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EXECUTIVE SUMMARY

Solid waste management has been influenced by the growing trend to apply market-based incentives to environmental problems. The impetus to reform solid waste management procedures in part stems from the increasing costs associated with solid waste disposal, thus encouraging municipalities to seek innovative ways to reduce solid waste generation. One method adopted by numerous municipalities in Maine is known as variable cost pricing. Alternatively, this system is referred to as unit pricing, volume-based fees, and pay-by-the-bag (PB). Under this system, waste collection fees are based on the volume of solid waste disposal. A household's solid waste disposal costs change with the number of bags of waste disposed since each bag is assessed a fee. As a result, the less trash set out for disposal, the lower the cost to the resident.

Unit pricing for municipal solid waste generation differs from the traditional method of charging a fixed annual fee to each household for waste disposal services, which in Maine is usually incorporated into the local property tax. The latter method provides little incentive for households to reduce solid waste generation for two reasons. First, the tax is not visible and instead is implicit in the property tax. Thus, there is often little association between the magnitude of the tax and the quantity of household waste requiring disposal. Second, regardless of the quantity of solid waste an individual household disposes, the cost is the same.

Over 50 municipalities have adopted PB programs in Maine. This study examines the types of PB programs adopted. In addition, this research analyzes the impact of PB systems on solid waste disposal and costs in 29 Maine municipalities, and compares these with a group of control towns that utilize traditional solid waste pricing. Among the study's major findings are:

- The sample of municipalities with pay-by-the-bag programs generate less than half the residential solid waste per capita produced by the control group. From October 1993 to September 1994, the amount of solid waste requiring disposal in PB towns averaged 0.19 tons per capita compared to an average of 0.43 tons per capita in the control group. Pay-by-the-bag programs are a significant factor in explaining variations in solid waste tonnages in our sample of data.
- An interesting finding among the municipalities in the control group is that those towns with a mandatory recycling ordinance had lower per capita annual solid waste tonnages than those towns without such a program (0.334 tons vs. 0.428 tons). This result should be interpreted with caution due to the small sample size, but it merits further investigation as an alternative to reducing solid waste tonnages.
- In 1993, municipalities with pay-by-the-bag programs on average spent 43 percent less per person on solid waste management than those without such a program. On average, PB municipalities spent $23.51 per capita compared to $41.20 in control towns.
- The total per capita cost of solid waste management in PB towns -- costs to the municipalities plus household expenditures on stickers and bags -- is 24 percent less than in control towns ($31.17 per person in PB towns and $41.20 in control towns).
- Other factors found to influence solid waste management costs are the type of collection system (curbside vs. drop-off) and the type of waste disposal system utilized (incinerator vs. landfill).

- There is little evidence of waste diversion from PB municipalities to neighboring towns, suggesting that waste shifting may not be significant problem.
- There is some indication that the implementation of PB programs contributed to an increase in backyard burning and roadside dumping. The incidence of roadside dumping apparently abates, however, within several months of the adoption of a pay-by-the-bag program.
- A survey of commercial establishments in pay-by-the-bag towns indicates that approximately 40 percent of the sample initially experienced sporadic episodes of illegal dumping of solid waste in commercial dumpsters. A majority of establishments either reported no increase in illegal dumping or a substantial reduction in the incidence of this within a few months of the program's adoption.

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I. Introduction

Growing concern about the impact of solid waste disposal on the environment has led to increased regulations on the siting and operation of landfills and a search for ways to reduce the amount of solid waste requiring disposal. In the state of Maine, many public landfills have been closed or are slated for closure and the siting of new private landfills has been banned. While these moves should have salutary effects on the environment, health, and water quality, reduction in disposal options has partly contributed to an increase in tipping fees (the per ton fee charged by landfills and incinerators for solid waste disposal). The continuing trend toward declining public revenues has required municipalities to seek options to reduce their SWM costs.

Among the responses has been the adoption of variable cost pricing or pay-by-the-bag (PB) systems. These systems are alternatively referred to as user fee, volume-based, unit pricing, and fee-incentive programs. While there is some variation among programs, the central feature is a pricing formula based on explicit per unit fees (e.g., per bag) for waste disposal. This contrasts with a conventional pricing system in which solid waste disposal costs are directly assessed as flat fees or are included in local property tax assessments. The economic rationale underlying PB systems is that households are presumed to have a greater economic incentive to reduce the amount of waste requiring disposal when fees are variable and visible. Variable cost pricing may also induce households to increase recycling activities. From the community's perspective, the net effect of adopting a PB system is anticipated to be a reduction in the quantity of waste requiring disposal and, potentially, a net saving in solid waste management costs. The latter condition will be obtained if the savings generated from reducing the amount of waste that requires disposal are greater than the additional costs associated with managing the PB program.

To date, over 50 municipalities in Maine have instituted variations on the PB system. Evidence from other states indicates that, in general, PB systems are effective in reducing solid waste generation (Morris, 1990; Guerrieri, 1994). Many public officials, however, continue to be skeptical about the viability of these programs in Maine. An important concern regards the cost-effectiveness of PB systems relative to conventional pricing systems. There has been little research on the impact of various features of PB programs which might influence the program's

success. Further, the potential for PB programs to reduce solid waste may be influenced by the demographic characteristics of municipalities, such as the population, the percentage of renters, the age distribution, and average household income. Little is known about how these factors interact with the economic incentives provided by PB programs. Finally, researchers have not considered the impact of PB programs on forms of waste diversion, including waste shifting to neighboring towns.

The purpose of this study is to investigate the impact of PB programs on residential solid waste disposal and on solid waste management costs. We also consider the impact of the adoption of PB programs on waste shifting to neighboring municipalities. Finally, the results of a survey of public officials and commercial establishments are presented which investigates the incidence of illegal dumping in PB and waste shifting to neighboring municipalities.

The study's findings are presented as follows. In Section II, the research methodology and data collection methods are described. Section III provides descriptive data of demographic characteristics of PB towns and the control group. That section also details the characteristics of PB programs and conventional solid waste pricing systems used in Maine. Section IV presents the results of analyzing the impact of PB systems on solid waste generation. In Section V, solid waste management costs in municipalities utilizing PB and traditional pricing systems are contrasted. This is followed by the presentation of results of an investigation into the extent of waste shifting to neighboring municipalities and of illegal dumping in PB towns in Section VI. The final section summarizes the study's major results and suggests areas for further research.

II. Methodology and Data Collection

The data sample is comprised of a sample of pay-by-the-bag municipalities and a control group of municipalities which utilize conventional pricing systems. The sample of pay-by-the-bag municipalities includes the 29 Maine municipalities which have had pay-by-the-bag systems in place for at least one year and which have recorded data on solid waste tonnages. The control group is comprised of municipalities which utilize conventional solid waste pricing systems but which are similar to the pay-by-the-bag municipalities in terms of population, median household income, and location.[(1)] In addition, control towns are at least 30 miles distant from any PB town. This greatly reduces the possibility that solid waste tonnages in control towns would be influenced by waste diversion from PB municipalities.

The methodology used to analyze the impact of PB programs contrasts the effect of solid waste pricing systems on solid waste disposal and solid waste management costs, after controlling for other demographic and program characteristics which might influence these variables (such as mandatory recycling ordinances or town composting programs). Utilizing this approach, solid waste generation and costs are compared among the two groups for a given year.[(2)] The cross-sectional comparison, which is facilitated by the use of a control group, is preferable to a time-series analysis which considers the before-and-after effects of the adoption of pay-by-the-bag systems. This is because over time, shifts in the level of economic activity can affect solid waste disposal. A cross-sectional analysis avoids the difficulties associated with controlling for the level of economic activity.

Several categories of data were required to carry out the analyses. Monthly municipal solid waste (MSW) tonnage data for the period 1993-94 were obtained from municipalities and regional incinerators. In some instances, the data included commercial waste tonnages. Since this study focuses on the impact of PB programs on residential waste, residential solid waste tonnages were derived from aggregate municipal solid waste tonnages and estimates of commercial waste percentages by municipal population in order to exclude commercial waste where necessary. The percentages of commercial waste utilized to adjust MSW data were those estimated by Criner, et. al. (1994). That research indicates that the share of commercial waste in municipal solid waste is greater, the larger the municipality. For example, in towns with a population of less than 1,000 persons, commercial waste is estimated to comprise 8 percent of MSW while in municipalities with populations exceeding 10,000 persons, commercial waste is 69 percent of MSW.

Data on characteristics of SWM programs and costs were obtained via a mail survey administered to public officials, and supplemented by telephone and personal interviews. Among the categories of information sought were expenditures on educational activities related to recycling, the existence of town-operated composting programs, descriptive data on solid waste ordinances, and the type of solid waste and recyclable collection methods utilized. Data collection took place from July to December, 1994.

Demographic data required to assess the factors which influence waste generation were obtained from 1990 U.S. Census. These variables, discussed in greater detail below, include median household income, average household size, and the number of renters. Population data were obtained from *1994 Maine Municipal Directory* which are more current than the 1990 Census population data. These data were adjusted where necessary to reflect changes in population due to the influx of summer residents. In those cases, towns officials provided adjusted population estimates from which weighted averages of annual populations were calculated.

Monthly solid waste tonnage data were also obtained for municipalities bordering towns which have adopted pay-by-the-bag programs in order to assess the extent of waste shifting. Information on the extent of illegal dumping was obtained from personal or telephone interviews with public officials, road crews, and a sample of commercial establishments conducted on a random sample of half the pay-by-the-bag towns.

III. Descriptive Characteristics of Pay-by-the-Bag and Control Municipalities and Solid Waste Pricing Systems

A. Demographic Characteristics

Pay-by-the-bag and control municipalities are similar in regards to several demographic characteristics which may affect solid waste generation (Table 1). For example, the average (of median) income in PB towns is $27,709 compared to $27,216 in the control group. While the average population of the sample of PB municipalities is slightly lower than that of the control group (2,521, compared to 2,628), the distribution of municipalities by population group is very similar.

Table 1.- A Comparison of the Demographic Characteristics of Pay-by-the-Bag and Control Municipalities

Characteristic	Pay-by-the-Bag Municipalities	Control Municipalities
No. of Municipalities in the Sample[1]	29	31
Average (of Median) Household Income	$27,709	$27,216
Average Population	2,521	2,628
Average Household Size (in persons)	2.845	2.721
No. of Municipalities by Population Group		
Less than 1000 persons	7	8
1000 - 2000 persons	10	10
2001 - 5000 persons	9	9
5001+ persons	3	3

Note: In some cases, two or more municipalities pool their solid waste for the purpose of disposal and therefore only pooled solid waste tonnages were available. As a result, the number of observations in the statistical analyses are fewer than the number of municipalities in the sample.

B. A Comparison of Solid Waste Management Systems in Pay-by-the-Bag and Control Municipalities

To date, over 50 municipalities have adopted pay-by-the-bag programs in Maine. The first program was implemented in 1989 but within the last year, 21 municipalities have adopted this program. The characteristics of pay-by-the-bag programs show some variation but the underlying concept of utilizing price incentives to induce waste reduction is common to all towns in the sample. A typical town sells to households a program instrument which is used to quantify the amount of waste requiring disposal. This may include plastic bags, stickers, tokens, punch cards, or tags that residents use or attach to the disposed item(s). In the majority of PB municipalities in the sample, the program instrument is sold at the town office while, in three cases, private businesses have been authorized to sell these items.

The method of collecting solid waste differs substantially among PB municipalities with 38 percent offering curbside collection, usually through the services of a private hauler (See Table 2). In some cases, municipalities contract directly with private haulers for these services, and in other cases, residents contract with haulers. The different methods of solid waste collection have implications for convenience and may influence household behavior regarding solid waste generation. Municipalities with curbside pick-up may encourage solid waste generation because residents do not have to haul waste to the disposal site themselves. In those towns without curbside pick-up, residents may try to minimize the number of trips to the transfer station and may therefore take steps to further reduce their solid waste.

Fees for solid waste disposal in PB programs are based on weight or volume. The majority of PB towns in the sample (72 percent) utilize the volume-based system of assessing fees. Half of these apply a $1 fee for each 30-33 gallon bag that bears an imprint identifying it as a program instrument. Only marked bags are allowed at the transfer station or are picked up by haulers. The remainder of the towns using the volume-based system require stickers that are sold at a cost ranging from $0.50 to $2.00 per sticker to be placed on bags of 30-35 gallon capacity. A variation on this system adopted by one town in the sample is to charge $1 per bag for the first two bags; the disposal cost for each additional bag is set at $2 per bag.[(3)]

Weight-based systems operate in 21 percent of the sample towns. In those municipalities where residents are responsible for transporting solid waste to the transfer station, the weighing is done at the station and residents pay accordingly. Otherwise, trucks conducting curbside pick-up are equipped with scales to weigh solid waste. The fee ranges from $0.02 to $0.06 per pound. Municipalities with weight-based PB programs generally set limits on the weight per bag (usually 25-35 lbs.). If bags of solid waste exceed this limit, the bags are not picked up or residents are charged an additional fee.

The remaining PB towns (7 percent) have solid waste restrictions that are both volume- and weight-based. For instance, in one case, a fee of $1 is applied to bags that are less than 30 gallons *and* less than 35 pounds. Additionally, in three of the PB towns in the sample, residents are given a number of "free" bags per week which do not require tags or stickers. Fees are only applied to solid waste that exceeds this limit.

Table 2.- A Comparison of Solid Waste Programs and Waste Disposal in Pay-by-the-Bag and Control Municipalities, 1993-94

Characteristic	Pay-by-the-Bag Municipalities	Control Municipalities
	38.0%	64.5%
Percentage of municipalities with town composting program	28.5%	29.0%
Per capita recycling educational expenditures	$0.21	$0.16
Percentage of municipalities with mandatory recycling	13.8%	13.0%
Percentage of municipalities which collect recyclables curbside	31.0%	40.0%
Percentage of municipalities using commercial landfill	7.0%	25.8%
Average annual residential waste disposal (in tons per person)	0.189 (0.08)	0.429 (0.16)

Average annual municipal solid waste management costs per capita	$23.51 (13.6)	$41.20 (19.0)
Average annual municipal plus total household solid waste management costs[1]	$31.17 (14.2)	$41.20 (19.0)

Note: Standard errors are in parentheses. Average annual per capita solid waste management costs were obtained by dividing total municipal solid waste management costs by the seasonally adjusted municipal population.

[1] Household solid waste management costs are total expenditures on tags, stickers, or bags utilized in municipalities with pay-by-the-bag solid waste pricing systems. These data were obtained from municipal offices which maintain records of revenues obtained from tag and sticker sales.

A number of towns have developed programs to complement their PB programs. Almost half the sample of PB towns have instituted town-operated composting programs to facilitate reductions in solid waste disposal. In some cases, public demonstrations are also held in which residents are trained in methods of home composting. In addition, more than half of all PB towns in the sample have educational programs to encourage recycling and composting. The goal of these programs is to enhance awareness about solid waste disposal costs and options, so that municipal residents reduce the amount of solid waste requiring disposal. On average, PB towns spend $0.21 per capita on these educational activities, which include newspaper advertisements, residential mailings, and volunteer presentations at schools and towns halls to distribute information on the details of recycling and composting.

Although this study deals primarily with the effects of the pay-by-the-bag program on residential solid waste, it should be noted that some commercial establishments are affected by these programs. About half of the towns sampled require commercial establishments to participate in the PB program. In some cases, however, businesses are assessed a fee per dumpster rather than per bag, with the fee varying with the size of the dumpster. Approximately 10 percent of the PB towns in the study offer firms the option of adopting the PB program or of contracting with a private hauler to pick up solid waste, with the firm bearing the burden of covering the costs of the contract.

Conventional pricing systems used by the control group are similar in that solid waste disposal does not require the payment of a unit fee. Nevertheless, a number of control towns have undertaken measures to reduce solid waste generation. A small percentage of control towns (13 percent) have a mandatory recycling ordinance. In addition, approximately a third have adopted town-run composting programs. Some municipalities also have educational programs to encourage recycling and composting, spending on average $0.16 per capita for this activity.

Table 2 summarizes comparative features of the sample of pay-by-the-bag towns and those of the control group. Expenditures on recycling and composting education are fairly similar, with PB towns spending $0.21 per capita compared to $0.16 in the control group. The percentage of municipalities with mandatory recycling ordinances is also similar among the two samples while almost twice as many of the PB municipalities (relative to the group of control towns) have town composting programs. The percentage of control municipalities that collect solid waste curbside is double that of PB towns, with the majority of the latter group requiring residents to drop off their solid waste at transfer stations. A larger percentage of control towns collects recyclables curbside (40 percent) than PB towns (31 percent). Further, PB towns largely rely on incinerators for waste disposal (93 percent) while a majority of control towns utilize private landfills.[(4)]

Of primary interest are the differences in per capita solid waste tonnages between PB towns and the control group. The average per capita solid waste disposed in PB towns in 1993 was 0.189 tons compared to an average of 0.429 tons per capita in control towns. Thus, the per capita quantity of solid waste disposed in PB towns was less than half that of control towns. Significantly, net municipal solid waste management costs are also lower in PB towns than in the control group. The annual average per capita expenditure in PB towns was $23.51 compared to $41.20 in the control group.[(5)] Even when the household's cost of solid waste disposal (e.g., the cost of bags and stickers) is added to the municipality's cost in PB towns, the average total per capita expenditures on solid waste management are lower ($31.17) than in the control towns ($41.20).

IV. The Impact of Pay-by-the-Bag Programs on Solid Waste Disposal

A. The Model

This section presents the results of an analysis designed to identify the factors that influence the quantity of residential solid waste. In particular, this analysis is concerned with determining the impact, if any, of pay-by-the-bag programs on quantities of residential solid waste requiring disposal. The analysis uses cross-sectional data comprised of a sample of PB and control municipalities described in Section II. The dependent variable in this analysis is per capita residential solid waste requiring disposal during the period October 1993 to September 1994.

The type of solid waste pricing system may affect waste flows, with prior research indicating that PB systems tend to reduce solid waste (Morris and Byrd, 1990; Guerrieri, 1994). Quantities of solid waste may be affected by a variety of others factors, however, which are controlled for in this analysis. The type of solid waste collection (drop-off and curbside collection) may influence these flows, with curbside collection having a positive effect on the quantity of solid waste.[(6)] Mandatory recycling ordinances are presumed to reduce solid waste. The existence of a town-operated composting project is hypothesized to have a negative effect on solid waste. Annual per capita expenditures on solid waste education may also affect waste flows. In particular, educational expenditures on solid waste education (e.g., recycling and composting) may serve to reduce solid waste disposal.

The percentage of renters relative to the total population of a community may explain waste flows (Hong, et. al., 1993). Rental arrangements may inhibit response to PB systems if renters do not bear the variable cost of solid waste generation. Thus, the ratio of rental units in a community may be positively related to solid waste. The average household size is expected to influence quantities of solid waste. The reason for this is that large households can be expected to buy in bulk and therefore may generate less solid waste per capita.

If people from small towns behave differently than people in large towns in purchasing habits and disposing waste, town population may be found to affect waste flows. The signs of the coefficients on town size are, however, are *a priori* ambiguous. Those in large towns may be more likely to have garbage disposals, but less likely to compost while rural residents may be more likely than urban residents to burn paper and wood waste.

The quantities of solid waste requiring disposal may be influenced by the income of the household (Eflaw and Lanen, 1979). On the one hand, high income households may be less likely to recycle and may have higher quantities of per capita solid waste requiring disposal. This will occur if the opportunity cost of time is relatively great in high income households and if they tend to consume more per capita than low income households. On the other hand, low income households may be more time constrained than high income households. This may result in a smaller negative effect of PB systems on solid waste in low income municipalities.

Previous research in the area of solid waste generation has not emphasized the potential influence of age on this variable. People in different age categories may, however, generate quantities of solid waste requiring disposal at different rates, depending on variations in consumption and expenditure habits. To capture the age effect, a summary statistic was developed from age distribution data using the ratio of persons over 55 to children under 5. For example, if populations over 55 have greater quantities of leisure time, we might expect that per capita solid waste is lower in municipalities with a higher age ratio since that group has more available time to recycle. On the other hand, this age group may be more likely to produce waste at home than working- and school-age populations. Also, the purchasing habits of retired persons suggest that that group will have lower quantities of solid waste for disposal relative to younger populations. In addition, households with young children are expected to have significantly greater quantities of solid waste requiring disposal (due to such necessary purchases as disposable diapers) and recycle less since these households tend to be time constrained. Given these conflicting effects on solid waste generation, *a priori* the sign on this variable is ambiguous.

The estimated equation is:

$$(MSW)_i = \%_0 + \%_1 PB_i + \%_2 COLLECT_i + \%_3 MAND_i + \%_4 COMPOST_i + \%_5 EDUC_i + \%_6 RENT_i + \%_7 HHSIZE_i + \%_8 POP_i + \%_9 MEDINC_i + {}_{10} AGE_i + 0_i,$$

where:

MSW = Municipal solid waste per capita, net of commercial waste.

PB = 1 if pay-by-the-bag system in $program_i$, and 0 otherwise.

COLLECT = 1 if curbside collection, and 0 otherwise.

MAND = 1 if mandatory recycling, 0 otherwise.

COMPOST = 1 if town composting project, 0 otherwise.

EDUC = per capita expenditures on education activities related to solid waste disposal.

RENT = ratio of renters to total population.

HHSIZE = average household size.

POP = population of area serviced by solid waste program.

MEDINC = median household income in community.

AGE = ratio of population above 55 years old to children under 5.

0_i = error term.

B. Results of Regression Analysis

The results of estimating the solid waste equation are presented in Table 3 as equation 1. Of primary interest is the impact of PB programs on solid waste tonnages. According to the results obtained in this analysis, PB programs are found to have a significant negative effect on residential solid waste tonnages. Municipalities that adopt PB programs can expect annual per capita solid waste tonnages to be 0.227 tons lower than under a conventional pricing system. The sign on the collection variable is positive, indicating that curbside pick-up of solid waste has a positive effect on the quantity of solid waste disposal. The coefficient on that variable is statistically insignificant, however. The results suggest that mandatory recycling ordinances and town composting programs reduce per capita solid waste, but these variables are not statistically significant. The coefficient on educational expenditures per capita is positive, but is insignificant. The percentage of municipal populations that are renters is also found to have a positive effect on per capita solid waste tonnages as predicted, but the coefficient on this variable is also insignificant. Of note is the positive coefficient on the population variable which, although statistically insignificant, suggests that municipalities with larger populations have higher per capita solid waste. This may be because residents in these towns have relatively more limited alternative disposal options such as backyard composting. In sum, the type of solid waste pricing program explains 58 percent of the variation in per capita residential solid waste tonnages between the municipalities in the sample.

The sample was split between pay-by-the-bag and control towns and re-estimated. The results are given in equations 2 and 3 in Table 3, respectively. In the sample of PB municipalities, only the collection method was found to explain significant variation in per capita solid waste. In particular, curbside pick-up has a positive impact on per capita solid waste, significant at the 95 percent level. According to the results obtained here, curbside pick-up raises annual per capita solid waste 0.123 tons.

Other variables in the regression that reflect solid waste program features and demographic characteristics are all found to be statistically insignificant. This result suggests that by far, the most powerful method to reduce residential solid waste disposal is to adopt pay-by-the bag incentive programs. The impact of other program characteristics (e.g., composting and educational programs) are either negligible or the random error of the model prohibited the regression model from estimating statistically significant parameters.

Table 3.- Determinants of Residential Solid Waste, 1993
Dependent Variable: Residential Municipal Solid Waste Per Capita in Tons

Variable	Equation 1 Full Sample	Equation 2 PB Towns	Equation 3 Control Towns
Constant	0.487 (2.18)**	0.176 (0.68)	0.224 (0.49)
PB	-0.226 (5.26)*		
COLLECT	0.064 (1.49)	0.123 (2.37)**	0.078 (1.35)
MAND	-0.054 (0.96)	0.037 (0.68)	-0.228 (2.41)**
COMPOST	-0.020 (0.39)	0.003 (0.06)	0.044 (0.52)
EDUC	0.030 (0.45)	0.006 (0.12)	-0.149 (0.58)
RENT	0.184 (0.60)	-0.609 (1.70)	1.086 (1.63)
HHSIZE	-0.067 (0.90)	0.054 (0.54)	-0.075 (0.70)
POP	0.001 (0.99)	0.001 (0.61)	0.001 (0.65)
MEDINC	0.001 (0.21)	-0.001 (0.96)	0.001 (0.82)

AGE	0.004 (0.29)	0.001 (0.07)	0.015 (0.53)
R^2	0.579	0.392	0.601
Number of observations	48	23	25

Notes: Numbers in parentheses are t-statistics for two-tailed tests. Equations were estimated using ordinary least squares.

* Significant at the 99 percent level.

** Significant at the 95 percent level.

Equation 3 presents the results of assessing the impact of various factors on per capita solid waste in control towns.[(7)] Mandatory recycling programs are found to substantially reduce per capita solid waste. The coefficient on this variable indicates that mandatory recycling programs can lower per capita solid waste by 0.228 tons per year, a magnitude that is comparable to that of PB programs. This suggests that each of these approaches may reduce residential solid waste -- that is, both market-based incentives and local ordinances which simply mandate that households sort and recycle solid waste can be effective in reducing the quantity of solid waste requiring disposal. This finding may be of interest to those municipalities concerned with the negative and regressive economic effects of PB programs on low income and/or large households. This result should be interpreted with caution, however, and considered only as preliminary since the number of control towns in the sample which have mandatory recycling programs is very small.

In sum, we have presented in this section results which indicate that an important determinant of solid waste disposal is the type of solid waste pricing system, with pay-by-the-bag programs contributing to an annual reduction of 0.226 tons of solid waste per capita. Curbside collection in PB towns is found to be positively correlated with per capita solid waste tonnages. This may be explained by the fact that in municipalities without curbside pick-up, residents may try to minimize the number of trips to the transfer station and may therefore take steps to reduce their solid waste. A second explanation for this correlation is that curbside pick-up is more likely to be the method of collection in large municipalities in which residents have fewer alternatives for reducing solid waste generation. Among control towns, mandatory recycling ordinances are also found to be negatively correlated with per capita solid waste although this result, as noted above, should be interpreted with caution.

The implications of these findings with regard to the impact of solid waste disposal reduction on incinerator fees for a representative municipality can be seen in Table 4. The regression results in Table 3 (equation 1) indicate that per capita solid waste disposal is 0.226 tons lower in PB towns than in control towns. In a town with a population of 2,500 persons, annual solid waste disposal will be 565 tons lower after the adoption of a PB program. Assuming an incinerator tipping fee of $45 per ton, total expenditures on solid waste disposal fees in a PB town would be $25,425

lower than in a community using conventional pricing. This is an illustrative example and should be interpreted with caution since other factors that influence costs are not included here. For example, in municipalities with curbside collection, cost savings may be greater. On the other hand, if there are economies of scale in solid waste collection and disposal, then unit costs of disposing of solid waste may rise, even if total costs fall.

Table 4.- The Impact of PB Programs on Solid Waste Disposal Tonnages and Incinerator Fees in a Representative Municipality

	PB Program
Impact of program on per capita solid waste disposal 0.226	-0.226
Population	x 2,500
Total decline in tons of solid waste disposal	565
Average incinerator tipping fee/ton	x $45
Change in expenditures on disposal fees	$25,425

Note: Average incinerator fee is from survey administered to PB municipalities.

V. The Impact of Pay-by-the-Bag Programs on Solid Waste Management Costs

This section presents the results of an analysis of the factors influencing net per capita solid waste management costs. In particular, the goal is to determine whether the adoption of PB programs can generate cost savings over conventional pricing systems. While PB programs may generate some savings if solid waste tonnages decline, the net per capita costs of these systems may be greater than those associated with conventional pricing systems if management and administrative costs are high and solid waste reduction marginal.

In order to estimate the effect of PB programs on cost, we have developed a simple econometric cost model. Two dependent variables are used in this analysis: 1) net municipal per capita solid waste costs, and 2) net total per capita solid waste costs. The data to calculate the dependent variables are for fiscal year or calendar year 1993 and were obtained from town officials. Net municipal per capita solid waste management costs (including recycling) are calculated as 1) gross solid waste management costs less 2) revenues received from the sale of recyclable material,[(8)] and less 3) revenues from the sale of PB programs instruments, such as bags and stickers.

An alternative way to define net solid waste costs is 1) gross municipal solid waste management costs less 2) revenues received from the sale of recyclable materials. This difference, divided by

municipal population, yields net total per capita solid waste costs and reflects municipal and total household expenditures on solid waste disposal. Household costs include out-of-pocket expenditures on bags, tags, and stickers. The cost analysis is conducted using both of the above definitions of net per capita solid waste costs as dependent variables.

Solid waste management costs can be influenced by a variety of variables in addition to the type of solid waste pricing system. Previous research suggests that there are economies of scale in solid waste management, and thus towns with larger populations are expected to have lower net per capita solid waste costs (Criner, et. al., 1991). The type of collection system may also influence municipal costs. The municipal costs associated with a drop-off collection system are assumed to be negligible and thus curbside collection is assumed to be more costly.[9] Finally, since the fee structure for usage of landfills can vary greatly from that of incinerators, a dummy or shift variable was allowed to model this effect.

The general form of the econometric model is:

$$NPC_i = \$_0 + \$_1 PB_i + \$_2 POP_i + \$_3 COLLECT_i + \$_5 LANDFILL_i + ,_i,$$

where:

$PB = 1$ if pay-by-the-bag system in $program_i$, and 0 otherwise.

POP = population of community.

$COLLECT = 1$ if curbside collection, and 0 otherwise.

$LANDFILL = 1$ if the program uses a landfill and 0 otherwise.

$,_i$ = the error term.

The results obtained from estimating the econometric cost model are presented in Table 5. The dependent variable in equation 1 is net municipal per capita solid waste management costs. The coefficient on the pay-by-the-bag variable is negative and significant at the 99 percent level, indicating that adoption of a PB program can lower net per capita solid waste costs relative to conventional solid waste pricing systems. According to our results, the reduction in annual per capita costs that can be attributed to the adoption of a PB program is \$19.86. The coefficient on the population variable is negative but small, indicating that less populated towns have lower solid waste management costs, contrary to our prediction. This may be explained by differences in programs and cost structures. For example, cities tend to have higher costs than towns (e.g., wages and rental fees tend to be higher). This variable was, however, statistically insignificant. The analysis shows that the measured costs of curbside pick-up are greater than for drop-off as anticipated, but this variable is also statistically insignificant.[10] Finally, municipalities disposing of their waste at landfills have significantly lower costs than those contracting with incinerators. Annual costs are \$13.28 lower per capita.

Equation 2 gives the result of estimating the cost model using net total solid waste management costs as the dependent variable. As expected, the cost reduction associated with the adoption of PB programs is less than in equation 1 ($12.67 compared to $19.86, respectively). This is explained by the fact that sticker or bag costs are borne by households. However, it is significant to note that even after accounting for this cost shift to consumers, there is a net saving associated with the adoption of PB programs. The coefficients on the remaining independent variables in this equation are similar in size and significance to those in equation 1 (with the exception of the COLLECT variable).

Table 5.- Determinants of Solid Waste Management Costs, 1993
Dependent Variable: Per Capita Net Solid Waste Management Costs[1]

Variable	Equation 1 Municipal Costs	Equation 2 Total Costs
Constant	43.654 (7.67)*	43.804 (7.59)*
PB	-19.861 (3.99)*	-12.669 (2.51)*
POP	-0.001 (0.41)	-0.001 (0.07)
COLLECT	3.263 (0.69)	1.951 (0.41)
LANDFILL	-13.285 (2.01)**	-13.588 (2.02)*
R^2	0.290	0.161
Number of observations	53	53

Notes: Numbers in parentheses are t-statistics for two-tailed tests. Equations were estimated using ordinary least squares.

[1] In equation 1, the dependent variable is net municipal solid waste management costs, measured as gross municipal solid waste management costs less the revenue from sale of recyclables and tags, stickers or bags. In equation 2, the dependent variable is net total solid waste management costs and includes municipal expenditures (as measured in equation 1) and household expenditures for tags, bags, or stickers. In both cases, costs are measured on a per capita basis.

* Significant at the 99 percent level.

** Significant at the 95 percent level.

VI. Pay-by-the-Bag Programs and Waste Diversion

There is anecdotal evidence that the adoption of pay-by-the-bag programs results in some waste diversion. Waste diversion activities, which can be defined as self-disposal options exclusive of home composting, may be both legal and illegal, beneficial and costly. Waste diversion takes place even when there is no PB system in place. For example, some households may drop off plastics and paper to commercial recyclers, and some roadside dumping may occur. The goal of this part of the study is to present preliminary data which assess the effect of the adoption of PB systems on two types of waste diversion: 1) waste shifting to neighboring municipalities without PB systems, and 2) waste diversion within PB municipalities.

A. Waste Shifting to Neighboring Municipalities

This section presents results of an analysis of the impact of the institution of PB programs on quantities of solid waste tonnages in neighboring locales. Time series data on quantities of solid waste requiring disposal have been assembled for thirteen municipalities neighboring PB municipalities, covering a one-year period prior to and following the institution of the PB program. Of course, municipal solid waste flows can be affected by a variety of factors, particularly the level of economic activity. Thus, a simple before-and-after comparison of municipal solid waste tonnages in neighboring towns does not isolate the extent of waste shifting from PB municipalities. To control for the effect of the economy on solid waste flows, we utilized a subset of control towns in the sample for which there were sufficient time series data to calculate the change in municipal solid waste tonnages. Thus, for simplicity, we assume that among the control group, the single factor affecting solid waste tonnages is changes in the level of economic activity.

Table 6 gives the results of this analysis. In order to estimate the extent of waste shifting to neighboring municipalities, we first calculated the percentage change in residential solid waste tonnages. The percentage change is the increase (or decrease) in residential solid waste tonnages from the year preceding the adoption of a PB program to the following year. From this number, we deduct the economy-related change in solid waste tonnages. The non-economy related change in solid waste (the last column in Table 6) is an indicator of the degree of waste shifting. A positive sign suggests that there has been waste shifting to the neighboring town. Thus, for example, the town of Burnham experienced a 6.6 percent increase in residential solid waste the year following Unity's adoption of a PB program. The average annual increase in residential solid waste in the control group during that same period was 2.5 percent. Assuming that a portion of Burnham's increase in solid waste was economy-related, we deduct 2.5 percent (obtained from estimating the change in MSW tonnages in the control group) from the 6.6 percent. The net effect of Unity's adoption of a PB program on Burnham after controlling for changes in the level of economic activity is estimated to be 4.1 percent. It is noteworthy that there is evidence of waste shifting in only four out of the thirteen cases examined here. In one of those cases (Vassalboro), the net increase in solid waste is negligible.

Table 6.- Neighboring Towns and Waste Shifting

PB Town	Neighboring Town	%) in Solid Waste	% in Solid Waste in Control Group	Non-Economy Related) in Solid Waste (in %)
Falmouth	Cumberland Yarmouth Portland	-5.8% -7.1 -2.2	-1.0% -1.0 -1.0	-6.8% -8.1 -3.2
Unity	Burnham	6.6%	2.5%	**4.1%**
Topsham	Bowdoin	-1.5%	5.8%	-7.3%
Tri-County[a]	Waldoboro/[b] Friendship	6.0%	6.2%	-0.2%
Hudson	Glenburn	-2.6%	6.3%	-8.9%
Troy	Burnham	16.0%	4.6%	**11.4%**
Raymond	Casco	-24.0%	4.6%	-28.6%
Sidney	Vassalboro	5.2%	4.9%	**0.3%**
Dresden	Wiscasset/Alna[b]	10.8%	6.3%	**4.5%**
Dixmont	Plymouth	4.7%	5.3%	0.6%

Notes: The non-economy related change in solid waste is calculated by subtracting the percentage change in solid waste in control towns from that in neighboring towns, under the assumption that changes in quantities of solid waste in control towns are economy-induced shifts.

[a] The Tri-County municipalities are Washington, Appleton, Union, Liberty, Palermo, and Somerville). These data are pooled.

[b] Solid waste for these municipalities is commingled and thus the data are pooled.

Further statistical testing to determine the extent of waste shifting was conducted using regression analysis of time-series monthly data.[(11)] The analysis is conducted for four neighboring towns for which the required monthly solid waste tonnage data and program information were available. As in the previous analysis, the model is designed to test for the effect on solid waste tonnages in neighboring towns of the institution of PB programs in nearby municipalities. In addition, we control for the season, the level of economic activity, and the presence of mandatory recycling programs.[(12)] Previous research indicates that solid waste tonnages are higher in the summer (Criner, et.al, 1994). In some towns, this may be related to the

influx of summer residents. Also, increases in the level of economic activity are hypothesized to have a positive impact on solid waste tonnages. Finally, the institution of mandatory recycling programs is predicted to have a negative effect on solid waste tonnages.[13]

The general form of the econometric model is:

$$MSW_t = \$_0 + \$_1 D1_t + \$_2 D2_t + \$_3 D3_t + \$_4 Index_t + \$_5 PB_t + \$_6 MAND_t + ,_t,$$

where:

t = time period (month).

MSW = per capita solid waste tonnages.

D1 = 1 for spring, 0 otherwise.

D2 = 1 for summer, 0 otherwise.

D3 = 1 for fall, 0 otherwise.

Index = Index of level of economic activity.

PB = 1 for presence of PB program, 0 otherwise.

MAND = 1 for presence of mandatory recycling program, 0 otherwise.

$,_t$ = error term in time period t.

The results of estimating this model for four neighboring towns are presented in Table 7. The variable of primary interest is PB. A positive and significant coefficient on this variable would indicate that waste shifting to the neighboring town had occurred upon the adoption of the pay-by-the-bag program. This variable is statistically insignificant in all four cases examined here. The level of economic activity also apparently has an insignificant effect on solid waste tonnages. Solid waste tonnages in equations 1-3 vary with the season. As expected, solid waste tonnages are highest in the summer. Finally, Wiscasset's adoption of a mandatory recycling program resulted in a significant decline in monthly residential solid waste tonnages (equation 3). These results are consistent with the findings above which suggest that the adoption of pay-by-the-bag program does not precipitate in a significant amount of waste shifting to neighboring towns. The variable Rho in Table 7 is the estimated first-order autocorrelation coefficient used to correct for the presence of serial correlation.

Table 7.- Results of Analysis of Waste Shifting to Four Neighboring Municipalities
Dependent Variable: Monthly Per Capita Solid Waste Tonnages

Variable	Equation 1 Burnham	Equation 2 Casco	Equation 3 Wiscasset[a]	Equation 4 Bowdoin
Constant	0.120 (0.45)	0.219 (1.03)	-0.062 (0.12)	-0.012 (0.14)
D1	0.011 (2.23)**	0.017 (3.07)*	0.010 (2.95)*	0.001 (0.52)
D2	0.011 (2.27)**	0.029 (5.73)*	0.017 (5.15)*	0.002 (1.06)
D3	0.007 (1.85)**	0.012 (2.41)**	0.008 (2.79)*	0.002 (1.44)
Index	-0.001 (0.34)	-0.002 (0.88)	0.001 (0.86)	0.001 (0.26)
PB	0.008 (1.06)	0.001 (0.25)	0.003 (0.83)	-0.001 (0.52)
MAND			0.017 (2.76)*	
Rho	-0.353 (1.46)			-0.112 (1.67)
Durbin Watson	2.113	1.694 7	2.164	2.02
R^2	0.377	0.762	0.692	0.235
Number of Observations	23	29	27	24

Note: The method of estimation is ordinary least squares. Equations 1 and 4 use a Cochrane-Orcutt correction for serial correlation. The numbers in parentheses are t-statistics.

[a] Data for Wiscasset include solid waste tonnages for Alna.

[*] Significant at the 99 percent level.

[**] Significant at the 95 percent level.

B. Waste Diversion in PB towns

In order to gather qualitative evidence on the effects of PB programs on the incidence of illegal dumping and other forms of waste diversion, a survey was conducted on a 50 percent random sample of PB towns. Interviews were conducted with public officials, road crews, and a sample of commercial establishments in person and by telephone. These groups were asked a series of questions designed to elicit information about changes in the incidence of 1) roadside dumping, 2) backyard burning, and 3) illegal dumping in commercial dumpsters after the implementation of PB programs.

Less than half of all PB towns surveyed reported initial increases in the incidence of roadside dumping after the adoption of PB programs. Most of those towns reporting this problem indicated that the magnitude of the problem was relatively small -- an occasional bag of waste found on the roadside and in one case, a truckload found in an abandoned gravel pit. Public officials were not able to quantify the amount of solid waste found on roadsides. In a number of cases, public officials were able to identify the source of the solid waste (by searching the waste for identification), and either fined the individuals responsible or gave them a warning. Three quarters of those towns reporting initial increases in roadside dumping have said that the problem has now abated.

A survey of commercial establishments in pay-by-the-bag towns to determine changes in the incidence of illegal dumping in dumpsters found little evidence of this problem.[(14)] The majority of those firms interviewed (60 percent) said that there was no increase in illegal dumping after the adoption of the PB program. A number of firms noted that the problem existed *before* the adoption of these programs and was largely correlated with the influx of tourists and summer residents. Among those firms reporting an increase in illegal dumping induced by the adoption of PB programs, a frequent response was to place locks on dumpsters.

A more frequent problem induced by the adoption of PB program is the apparent increase in backyard or barrel burning. Slightly more than half the sample of PB towns receiving in-depth interviews noted an increase in the incidence of this practice with 30 percent indicating that the problem continues. (None of those municipalities reporting continuing problems with backyard burning have curbside pick-up of recyclables). This may reflect the rural character of the sample of PB towns as well as the difficulty of monitoring this practice (unlike, for example, roadside dumping).

Another form of waste diversion, broadly speaking, could be described as the commingling of non-recyclable solid waste with recycled goods. Among the towns surveyed, there was little evidence of a decline in the quality of recyclables (i.e., commingling) after the adoption of a PB program. While 36 percent of the towns surveyed reported that this practice was an initial problem, all of those noted that the quality of recyclables returned to normal within a short period of time.

VII. Summary and Conclusions

The results of this study suggest that pay-by-the-bag programs are associated with relatively lower per capita solid waste tonnages relative to conventional pricing systems. Pay-by-the-bag towns also have lower municipal solid waste management costs per capita. Even if we include household expenditures in solid waste management costs, pay-by-the-bag municipalities are found to spend less on solid waste management per capita than towns with conventional pricing systems.

An interesting finding is that residential per capita solid waste tonnages are lower in those control towns with a mandatory recycling programs than in the control towns without such a program. For those municipalities concerned about the negative impact of PB programs on low income households as a result of the higher cost per household of waste disposal, the latter option may be attractive. Because the primary focus of this study is to investigate the impact of PB programs on solid waste tonnages and costs, we were not able to fully analyze the relationship between mandatory recyling programs and solid waste tonnages. The results obtained here suggest that this might be a fruitful area for further study, however.

The data indicate that waste diversion and waste shifting are not serious and extensive problems. While there is some evidence that these practices exist, a large percentage of PB towns report that the incidence of illegal dumping has tapered off within several months of the adoption of the program. In part, this may be due to the fact that some commercial establishments have themselves taken measures to reduce the incidence of illegal dumping. Therefore, continued monitoring of this practice may be warranted. In addition, there is some evidence of an increase in backyard burning in PB municipalities after the adoption of unit pricing programs. This practice may explain the relatively large difference in per capita solid waste tonnages between towns with conventional pricing and unit pricing programs. Due to data limitations, we were not able to estimate the quantity of waste diverted in this fashion. To the extent that this poses environmental hazards, an evaluation of the extent of this practice may be an important area of future research.

Since 1989, solid waste pricing and management systems used by Maine municipalities have changed greatly. These shifts are related to the rising costs of incinerator disposal and the state-mandated requirement that towns recycle 35 percent of solid waste. A number of towns in Maine have only recently closed public landfills and now rely on private landfills or incinerators for waste disposal. It appears that the bulk of infrastructure adjustments have been made, but solid waste programs are still in flux. For example, recycling markets are not yet fully developed, with the result that some towns have revenues from the sale of recyclables while others have recycling contracts that impose a net cost on towns. Recycling tonnage data are also very sparse, making it

difficult to analyze the impact of PB and mandatory recycling programs on quantities of waste recycled. Also, solid waste tonnage data are as yet still very difficult to obtain since in the past many towns did not record these data. In the next several years, as the recycling market becomes more fully developed and recordkeeping on quantities of waste recycled is more systematic, research in this area should be more feasible than at present.

APPENDIX A

Pay-per-Bag Towns	Control Towns	Neighboring Towns
Appleton	Bethel	Abbot
Arundel	Brewer	Alton
Belfast	Bristol, S. Bristol	Belgrade
Bowdoinham	Brownville	Belmont
Castine	Cornville	Biddeford
Dixmont	Dedham	Bowdoin
Dresden	Eddington	Brownfield
Durham	Embden	Brunswick
Falmouth	Frankfort	Burnham
Fryeburg	Hampden	Carmel
Hudson	Harrison	Casco
Knox	Hartford	Cumberland
Liberty	Hollis	Eastbrook
Monson	Industry	Freedom
Palermo	Lee	Friendship
Raymond	Limington	Gardiner
Richmond	Machiasport	Glenburn
Searsmont	Mattawamkeag	Gouldsboro
Sidney	Mechanic Falls	Jefferson
Somerville	Minot	Kenduskeag
Sullivan	Newport	Lovell
Thorndike	North Berwick	Lyman
Topsham	Parkman	Monmouth
Troy	Parsonsfield	Montville
Union	Readfield	New Gloucester
Unity	Smithfield	Penobscot
Warren	Stonington	Plymouth
Washington	York	Poland
Winter Harbor		Portland
		Pownal

Searsport
Vassalboro
Waldo
Waldoboro
Willimantic
Windsor
Yarmouth

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Notes:

1. [1] A list of the municipalities utilized in the study can be found in Appendix A.

2. [2] The method of analysis is multivariate regression analysis.

3. In this case, the first two bags require a single ($1) sticker and additional bags will only be picked up if they have two stickers attached.

4. Those towns with publicly owned landfills were excluded from the control group because of the lack of data on solid waste tonnages.

5. Data on tipping fees were incomplete, with approximately 70 percent of municipalities reporting these figures. Calculating the 1993 average of those municipalities on which there were

data, tipping fees averaged $49.27 per ton for the control group and $48.75 for pay-by-the-bag municipalities.

6. [6] The frequency of curbside pick-up may also influence solid waste flows (Wertz, 1976). Generally, it has been hypothesized that the less frequent the solid waste pick-ups, the more likely households will be to reduce solid waste, and to recycle and compost. A separate variable for the frequency of solid waste pick-ups is not included in this model because all municipalities with curbside collection have weekly pick-up. As a result, a variable measuring the frequency of curbside pick-ups would be identical to the dummy variable which indicates curbside pick-up or drop-off.

7. [7] A Chow test and a modified White test, used to test for the presence of heteroskedasticity, were insignificant at the 90 percent level.

8. A number of the municipalities in the study's sample reported no revenues from recyclables. Still others paid a substantial fee to dispose of recyclables.

9. [9] In municipalities without curbside pick-up, it should be noted that households absorb the cost of transporting waste to disposal sites. Unfortunately, data limitations prevented estimation of the cost to households.

10. Also, it should be recalled that drop-off collection systems result in costs to individual households but because of data limitations these are not reflected in net total per capita costs in equation 2.

11. Time series cross-sectional data for PB, control, and neighboring towns may also be used to test for waste diversion. An analysis of the data using this methodology is the object of future research by the authors.

12. Dummy variables are used to control for season. The omitted variable is winter.

13. Only one out of the four neighboring towns introduced a mandatory recyling program during the period of analysis (August 1992 - December 1994).

14. [14] In most cases, three commercial establishments were interviewed in each PB town randomly selected for in-depth interviews. In order to develop a random sample of firms to interview, a list of commercial establishments with dumpsters was obtained from a major waste hauler (a broader list of commercial establishments was sought but other waste haulers were reluctant to share their list of customers). From the list of commercial establishments in the PB towns randomly selected for in-depth interviews, three firms were contacted to obtain information on illegal dumping. The exception to the number of firms interviewed were small towns. In those cases, there may have been fewer than three establishments in town.