Market-Based Incentives and Residential Municipal Solid Waste
Author(s): Marie Lynn Miranda, Jess W. Everett, Daniel Blume, Barbeau A. Roy, Jr.
Source: *Journal of Policy Analysis and Management*, Vol. 13, No. 4 (Autumn, 1994), pp. 681-698
Published by: John Wiley & Sons on behalf of Association for Public Policy Analysis and Management
Stable URL: http://www.jstor.org/stable/3325493
Accessed: 15/11/2010 03:08

Market-Based Incentives and Residential Municipal Solid Waste

Marie Lynn Miranda
Jess W. Everett
Daniel Blume
Barbeau A. Roy, Jr.

Abstract

Coalitions of free-marketeers, politicians, and environmentalists increasingly are turning to the use of market-based incentives in formulating environmental policy. One promising application of market-based incentives is in the management of residential municipal solid waste. This article focuses on unit-based pricing programs established in conjunction with community recycling programs. Using data gathered through telephone and mail surveys of 21 cities, we demonstrate the strong potential for unit pricing to improve the efficiency of residential solid waste management.

Coalitions of free-marketeers, politicians, and environmentalists increasingly are advocating the use of market-based incentives rather than command-and-control regulation in the formulation of U.S. environmental policy. This alternative approach is perhaps best exemplified by the publication of *Project 88* and its 1992 update [Stavins et al., 1988, 1992]. Both of these nonpartisan reports provide innovative recommendations that would harness market forces to achieve higher levels of environmental protection at lower costs to society. The superior economic efficiency result associated with market-based incentives, however, is dependent on, among other things, the number and type of players in the market, the relative competitiveness of the market, the need for monitoring and enforcement, information requirements, and transaction costs. Unit pricing of residential municipal solid waste (MSW) represents one promising application of market-based incentives to environmental policy and management.

BACKGROUND TO THE PROBLEM

The U.S. populace generates an enormous amount of garbage—in quantities that have grown dramatically over the past several decades. In 1960, the United States produced 88 million tons of municipal solid waste. By 1988,

Journal of Policy Analysis and Management, Vol. 13, No. 4, 681–698 (1994)

Published by John Wiley & Sons, Inc. CCC 0276-8739/94/040681-18

this figure had risen to 180 million tons [Franklin Associates, 1990]. Per capita waste production increased from 2.7 pounds per person per day in 1960 to 4 pounds per person per day in 1988. By 2000, the U.S. Environmental Protection Agency predicts that per capita MSW generation will rise to 4.4 pounds per person per day [U.S. EPA, 1990]. Communities across the United States face a growing challenge regarding how best to collect and dispose of MSW in an economically efficient and environmentally sensitive manner.

Several highly publicized solid and hazardous waste incidents (Love Canal, Times Beach, and the Long Island garbage barge) raised public consciousness about the importance of safe disposal and of minimizing the production of both solid and hazardous waste. A study sponsored by the U.S. Environmental Protection Agency examined 163 landfill case studies chosen as nationally representative. This study found groundwater contamination or adverse trends at 146, or 90 percent, of the sites. In addition, landfill disposal of ash from facilities incinerating MSW created a contamination risk, as fly ash or mixed fly and bottom ash often failed EPA toxicity tests [Denison and Ruston, 1990]. A growing not-in-my-backyard syndrome and stricter federal legislation have made it more difficult and more expensive to site and construct new landfills. As a result, local governments have begun to develop integrated solid waste programs (ISWPs), which emphasize a broad mix of MSW management policies.

Policies designed to address the solid waste management dilemma can be divided into three categories. The first category, *disposal*, includes decisions on how and where to construct a landfill or incinerator. Solid waste managers choose sites based on some weighted average of geologic suitability, economic feasibility, and political palatability. Design and operation plans represent a balance between minimizing the pollution potential and associated ecological and human health risks of MSW disposal and minimizing the costs of managing such facilities. The second category of policies, *materials diversion*, diverts waste from the local landfill. Activities include recycling, composting, illegal disposal, storage, or transport to adjacent counties. The third category, *source reduction*, attempts to decrease the total amount of waste generated. This category includes recycling, packaging waste reduction, or a switch from throwaways to reusables.

UNIT PRICING OF RESIDENTIAL MUNICIPAL SOLID WASTE

Historically, community MSW management programs have provided residents with little incentive either to limit the amount of garbage they produce through source reduction, or to divert waste from the local disposal option through composting and recycling activities. Most cities in the United States charge residents a fixed annual fee for waste collection services regardless of the amount of waste they generate. There may be a limit on the number of containers a household can place curbside, but this number is generally high and unenforced. Whether families regularly place two or six bags curbside on collection day, they pay the same amount of money. In addition, the flat fee is usually taken from a general tax assessment; and residents are often unaware of the actual portion of their assessment that goes toward local MSW management. Despite the additional social costs generated by the "extra" waste in the form of higher landfill tipping fees, labor costs, and other collection costs, residents essentially face a zero private marginal cost to garbage production. As a result, they may overparticipate in the waste production market and underparticipate in source reduction and materials diversion activities.

Unit pricing schemes—an alternative to the traditional flat fee approach—charge households for waste collection and disposal services based on the amount, measured by volume or weight, and type of material collected. Unit pricing schemes are usually run in combination with an aggressive recycling program in order to create viable substitutes for waste disposal and to engender a collective commitment to resolving the community's MSW management problem. These programs usually do not charge for the collection of recyclable or compostable materials if residents separate them from the rest of the solid waste stream.

Solid waste program managers usually encourage recycling by appealing to residents' sense of contributing to the environment or reducing overall solid waste costs. In contrast, unit pricing provides residents with a direct price incentive to reduce their production of MSW [Office of Technology Transfer, 1990; Platt, et al., 1990]. As a result, recycling programs in cities with unit pricing tend to have higher recycling program participation levels and higher recycling rates in comparison to cities without unit pricing [Ademec, 1991; Skumatz, 1989a, 1989b; Sproule and Cosulich, 1988; Riggle, 1989; Goldberg, 1990; Skumatz, 1990]. Furthermore, unlike recycling programs, unit pricing encourages both source reduction and waste diversion activities. By taxing a "bad" activity, unit pricing may lead to greater awareness of the economic and environmental costs of waste disposal. Thus, in addition to trying to save money on waste bills, residents may begin to view source reduction and materials diversion as intrinsically "good" activities. Currently, landfill tipping fees—the charges assessed for dumping MSW at a landfill—range from $10/ton, where state laws are less stringent and land costs are low, to over $150/ton, in states with tough disposal laws, high land costs, and active public opposition to new disposal facilities. Higher landfill tipping fees make market-based incentives more effective, as the savings related to reducing MSW flows to landfills can be included when calculating materials diversion and source reduction costs and benefits.

IMPLEMENTING UNIT PRICING

Economic theory suggests that the traditional flat fee for collection services will lead people to generate inefficiently high levels of MSW. Because they face a zero price for increments in MSW collection services, residents will consume collection services out to point CS_{TS} in Figure 1, under the traditional system. To maximize economic efficiency, however, municipalities should charge according to marginal costs. As shown in Figure 1, this would entail charging P_{MCP}, with CS_{MCP} as the resulting level of collection services.

Economic theory argues in favor of marginal cost pricing. In practice, however, communities that have adopted some form of unit pricing usually turn to average cost pricing or two-tier pricing. Average-cost pricing sets the unit price equal to the average total cost per unit. To calculate this cost, the community estimates the total amount of solid waste it expects to dispose of in the next year. It then computes the total cost incurred and divides by

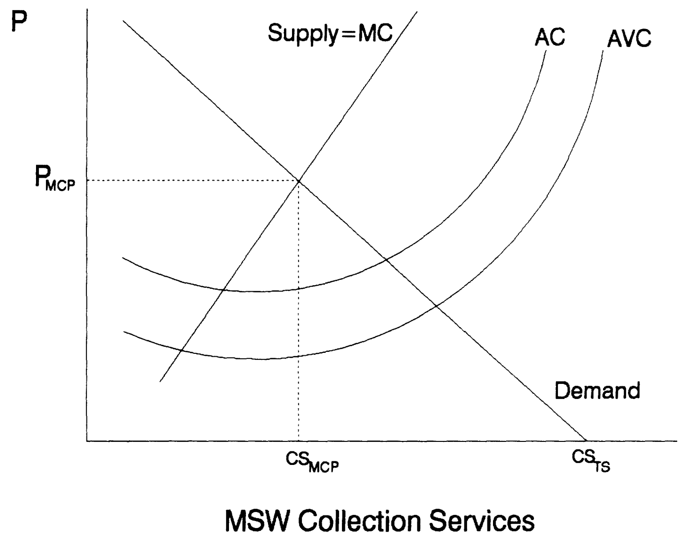

Figure 1. Demand for MSW collection services under the traditional system (CS_{TS}) and under marginal cost pricing (CS_{MCP}).

the number of bags expected. This yields a unit price that includes the fixed and variable costs incurred by collecting each unit of MSW. If average costs are computed correctly, average cost pricing is more efficient than the traditional system, but less efficient than marginal cost pricing, as shown in Figure 2. The community will charge P_{ACP}, with CS_{ACP} as the resulting level of collection services.

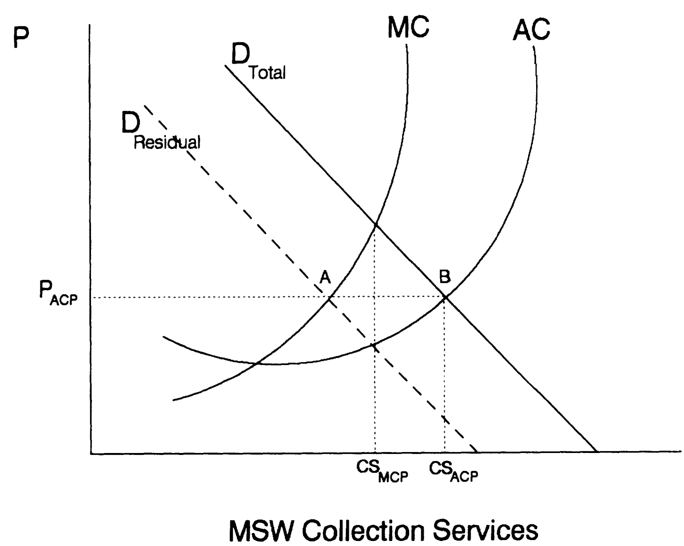

Figure 2. Demand for MSW collection services under average cost pricing (CS_{ACP}) and under marginal cost pricing (CS_{MCP}).

If solid waste managers underestimate average costs, then average cost pricing becomes relatively less efficient, as the community will end up somewhere to the right of CS_{ACP}. If, however, average costs are overestimated, the community will end up somewhere to the left of CS_{ACP}—and closer to the efficiency maximizing point CS_{MCP}. If average costs are vastly overestimated, then the community will end up to the left of CS_{MCP}, and it will underproduce MSW from an economic efficiency standpoint.

Under two-tier pricing, residents are charged two fees for MSW collection services. The first fee is flat and covers some minimum level of service, such as one can or one bag per week. The second fee is unit-based and varies with any additional bags or cans collected from the household during a particular week. This system leaves a residual demand curve for MSW collection services once the minimum level of service is subtracted from the total demand curve, as shown in Figure 2. The relative efficiency of this system depends on the minimum level of service provided and the manner in which the unit price is set. If the minimum level of service is set equal to the distance AB, and the unit price is set equal to P_{ACP}, then two-tier pricing will be as efficient as average cost pricing. In general, the smaller the minimum level of service is, and the more closely the unit price is based on marginal cost, the more likely two-tier pricing will maximize economic efficiency.

Most unit-pricing programs can be categorized as either "bag," "sticker," or "can" systems, depending on how the household pays the unit fee. Bag systems require residents to purchase specially marked trash bags from local stores or town offices. The purchase price includes all estimated fixed and variable costs associated with the collection and disposal of that bag. Refuse haulers will only pick up these specially marked bags along their routes. Sticker systems require residents to purchase a packet of stickers and then place one sticker on each bag set at the curb for collection. The cost per sticker, like the special bag, covers all costs associated with the collection and disposal of the bag on which it is placed. In the can system, households subscribe to cans provided by the municipality. Fees depend on the number and size of the cans.

The sticker system offers the flexibility of allowing residents to dispose of large items without having to make special requests for collection. Sticker programs usually determine ahead of time the number of stickers required for different large or bulky items, like home appliances or furniture. Bag systems usually handle these items with a separate billing to the resident. Stickers can also be mailed to the household, whereas bag systems require residents to go to specified locations to purchase the special bags. One weakness of the bag or sticker systems involves the reliability with which the container accurately measures the volume/weight of waste inside—and thus the marginal contribution of waste as it affects landfill capacity.

Since most landfill tipping fees are based on weight, it would be more accurate to charge residents per pound of garbage rather than per unit of volume. The weight of a 33-gallon bag can range anywhere from 2 or 3 pounds up to 50 or 60 pounds, depending on its contents. Since garbage trucks are equipped with compactors, the volume of the garbage collected matters less. The additional cost of putting scales on garbage trucks (estimated at between \$3000 and \$7000 per truck), the additional time required to weigh and record each bag per household, and administrative complications associated with weight-based pricing have kept communities from adopting this more accurate unit pricing scheme [Minnesota Office of Waste Management, n.d.]. Several communities, however, have conducted or are conducting weight-based pilot projects. Based on preliminary results, it is likely that full-scale weight-based collection systems will be implemented in the near future.

For the community solid waste manager who has decided that unit pricing will help meet the community's need for source reduction and materials diversion, there is still the difficult task of deciding which combination of recycling and composting services, if any, to offer in conjunction with the unit-pricing program. Despite clear policy trade-offs, solid waste managers tend to focus on waste flows, program costs, and administrative requirements, rather than on levels of economic efficiency, in making these decisions.

POTENTIAL IMPACT OF UNIT PRICING ON MSW PRODUCTION

Unit pricing programs are most commonly run in conjunction with an aggressive recycling program. Recycling programs, with the exception of aluminum, usually result in net revenue losses, even if averted landfill tipping fees are included in the cost–benefit analysis. Consequently, solid waste managers must consider potential trade-offs between encouraging source reduction and materials diversion activities. Comparing the optimality conditions under a traditional flat-fee system, a unit-based pricing system, and a unit-pricing system in conjunction with a recycling program can give us several insights regarding what behavior we might expect when a unit-pricing program is implemented.[1]

1. The higher the unit price is, the stronger will be the source reduction and recycling response. Of course, if consumers begin to feel that the unit price is at an unreasonably high level, they may respond by disposing of their garbage illegally.
2. The degree to which consumers can respond to higher unit prices by source reducing will depend on the relative substitutability between high-garbage-generating and low-garbage-generating goods (a substitution effect). Even without any substitutability, however, some source reduction will occur because of the income effect created by the higher price on MSW collection services.
3. Consumers may begin to demand goods that generate the same consumption utility but less garbage; that is, the same product with less packaging waste. Given national product distribution systems, unit-pricing programs may exhibit some economies of scale. The more that communities adopt these systems, the more people will demand less packaging. As companies respond to this demand, it will be easier for individuals to undertake source reduction activities.
4. Making recycling more convenient may decrease the incentive to source reduce. This phenomenon also interacts with points two and three above.

[1] We present the intuition here; formal modeling of the problem is available from the authors upon request.

Table 1. Demographic data for 21 sample cities, compared to national average.

City	Pop.	Percentage white	Median age	Median housing value ($)	% attained h.s. or higher	% attained BA or higher	Per capita income ($)	Median household income ($)	% below poverty	% unem-ployed
Antigo, WI	8276	98	36.5	34,500	72.8	13.8	10,291	19,311	16.9	6.8
Charlemont, MA	1249	98	35.0	105,300	80.1	22.7	13,451	28,929	9.4	6.4
Downer's Grove, IL	46,858	92	34.6	143,900	89.7	40.0	20,891	48,226	2.5	2.9
Grundy Center, IA	2491	100	41.3	38,000	76.5	14.6	11,744	24,159	8.4	2.5
Hancock, VT	340	93	37.4	70,400	72.9	13.8	9144	21,875	17.8	9.0
Hartford, VT	9404	98	34.7	110,500	82.1	23.5	15,097	31,512	9.0	5.4
Harvard, IL	5975	85	30.5	75,400	71.0	12.2	13,337	29,882	7.6	4.4
High Bridge, NJ	3886	97	32.3	158,400	85.9	36.1	19,004	49,069	4.9	2.3
Huntingburg, IN	5242	98	33.8	41,900	66.4	8.3	10,862	24,375	11.2	7.4
Ilion, NY	8888	98	34.2	49,000	71.8	14.8	10,389	22,115	14.2	6.0
Ithaca, NY	29,541	80	22.2	95,600	86.0	50.2	9213	17,738	39.4	4.9
Lisle, IL	19,512	88	30.5	162,800	93.7	49.7	23,952	49,712	2.8	2.3
Mt. Pleasant, IA	8027	95	33.6	49,500	78.1	16.9	11,629	23,757	9.5	3.8
Mt. Pleasant, MI	23,285	94	21.8	59,700	84.7	39.3	9032	19,185	38.7	8.2
Perkasie, PA	7878	98	31.6	127,400	81.1	22.1	18,102	39,193	2.4	1.6
Plains, PA	4694	99	42.2	49,800	69.9	13.0	10,979	22,527	9.0	8.8
Quincy, IL	39,681	95	36.0	41,800	73.6	14.5	11,708	21,325	15.0	6.2
River Forest, IL	11,669	93	36.4	258,900	95.0	59.5	32,569	62,469	2.4	1.9
Saint Charles, IL	22,501	96	33.4	137,400	88.4	36.1	20,794	46,655	2.5	2.6
Weathersfield, VT	2674	99	37.5	91,100	68.2	16.9	13,227	27,181	7.5	9.7
Woodstock, IL	14,353	94	31.9	92,300	77.3	16.5	13,965	31,458	6.6	2.9
Sample averages	13,163	95	34.0	94,933	79.0	25.0	14,732	31,460	11.0	5.0
National averages		76	32.9	79,100	75.2	20.3	14,420	30,056	13.1	6.4

DATA COLLECTION AND ANALYSIS

Until about five or six years ago, unit pricing for residential municipal solid waste was used in only a handful of cities across the country. Not until 1988, when several cities in Illinois, Pennsylvania, New York, and New Jersey began unit pricing on an expanded scale, did much discussion about the effects of unit pricing begin. As tipping fees began to rise across the country and word spread about the success of these pioneering cities in reducing solid waste levels and increasing recycling levels, unit pricing quickly appeared in other communities. In just five years, the number of communities instituting unit-pricing programs has grown to over 1000 [Skumatz and Zach, 1993].

Because these programs are so new, there have been few studies evaluating the effects of unit pricing on household waste generation behavior. A scarcity of reliable data on waste and recycling levels also limits the study of unit-pricing programs. Very few communities kept data on solid waste and recycling levels before unit-pricing programs were implemented. The data presented in this article are based on information obtained from 21 cities through extensive telephone and mail surveys conducted over an 18-month period between July 1990 and January 1992.

These cities are by no means nationally representative. Table 1 presents

Table 2. Summary statistics on unit-pricing programs.

	Average	High	Low
Unit price	$1.07	$2.00	$0.68
Change in tonnage landfilled	−40%	−74%	−17%
Change in tonnage recycled	+126%	+456%	+3%
Change in total tonnage generated	−30%	−63%	−10%
Percentage of total waste recycled	19%	39%	2%

demographic information on the sample and compares the sample to U.S. averages. The sample consists of fairly small cities, about half of which can be considered suburbs to large urban centers. In general, these cities have populations that are more Caucasian, somewhat older, with higher median housing values, higher levels of educational attainment, higher per capita and median household income, and lower poverty and unemployment rates than the national average. While clearly not nationally representative, these were the *only cities* we were able to find that had both before and after data on the effects of implementing a unit-pricing program on MSW generation and recycling levels.[2] In addition, unit-pricing programs are most likely to be successful in lower density urban neighborhoods, suburban areas, and rural communities where regular curbside pickup of residential MSW is the norm [Menell, 1990]—in other words, places like those in our sample.

It is also important to remember that the city or private haulers who reported the figures for waste reduction and recycling increases are first and foremost in the business of collecting trash, not in collecting data for others to analyze. Some cities can report the changes in waste levels relatively accurately because their systems were set up so that actual measurements of garbage truck weights were made before and after unit-pricing programs were put into effect. Other cities can only estimate weights from the number of truckloads sent to the landfill, since each truck was never actually weighed. The data can, however, help us describe observed household waste production behavior and determine how generally responsive individuals are to changes in the pricing of municipal solid waste collection services.

Table 2 summarizes the important averages and ranges for changes in disposal practices upon implementation of unit-pricing programs in our 21-city sample. These results suggest that unit-pricing and recycling programs can have a dramatic effect on solid waste flows. Every city studied reported significant reductions in waste disposed at landfills in the year following adoption of unit pricing. Overall, the average reduction in tonnage landfilled was 40 percent, with a high of 74 percent and a low of 17 percent. Table 3 documents the reduction in landfilled waste for each of the 21 cities. Six of

[2] Miranda is in the process of developing a new survey instrument whose results would support evaluation of unit-pricing programs in cities that only have after data.

Table 3. Change in tonnage landfilled in response to implementation of unit pricing.

City	Change in tonnage landfilled (%)
Antigo, WI	−50
Charlemont, MA	−37
Downer's Grove, IL	−52
Grundy Center, IA	−32
Hancock, VT	−33
Hartford, VT	−17
Harvard, IL	−33
High Bridge, NJ	−18
Huntingburg, IN	−74
Ilion, NY	−51
Ithaca, NY	−31
Lisle, IL	−53
Mt. Pleasant, IA	−49
Mt. Pleasant, MI	−44
Perkasie, PA	−54
Plains, PA	−49
Quincy, IL	−41
River Forest, IL	−19
Saint Charles, IL	−41
Weathersfield, VT	−36
Woodstock, IL	−31

these reported reductions of 50 percent or more. Another 12 fell in the 30–49 percent range, and 3 reported a 15–20 percent reduction.

Unfortunately, our limited data sample was not able to support a multivariate statistical analysis to quantify the impact of different factors on changes in tonnage landfilled. We were, however, able to group the cities in various ways in order to compare average changes in tonnage landfilled across different program characteristics. These groups are presented in Table 4.

In our sample, 19 cities use some rough approximation of average cost pricing, and 2 cities use two-tier pricing. The average decrease in tonnage landfilled was much bigger for the cities using average cost pricing (42.5 percent) than for those using two-tier pricing (18.5 percent). This is consistent with the theoretical analysis presented in this article, because the minimum level of service was quite high in the two-tier pricing cities—thus dampening the price incentive component of the program.

We also divided the cities according to the relative aggressiveness of their recycling programs. Mandatory with curbside recycling constituted "very aggressive"; voluntary with curbside recycling constituted "aggressive"; and voluntary with drop-off recycling constituted "average." Not surprisingly, unit-pricing programs accompanied by "aggressive" recycling had bigger average decreases in tonnage landfilled (43.4 percent) then programs with "average" recycling (33.8 percent). In contrast, the "very aggressive" recycling cities had average decreases in tonnage landfilled (34.0 percent) *roughly equivalent* to the "average" recycling cities. This may be accounted for by one of two explanations. First, communities may have had a strong environmental ethic prior to the introduction of unit-based pricing, which resulted in the

Table 4. Unit-pricing city groupings.

Grouping	Number of cities	Change in tonnage landfilled (%)
Pricing method		
Average cost pricing	19	−42.5
Two-tier pricing	2	−18.5
Aggressiveness of recycling program		
Very aggressive (mandatory with curbside recycling)	3	−34.0
Aggressive (voluntary with curbside recycling)	14	−43.4
Average (voluntary with drop-off recycling only)	4	−33.8
Level of unit-based fee		
High (fee > $1.25)	3	−41.3
Medium ($1.25 > fee > $1.00)	12	−41.2
Low (fee < $1.00)	4	−47.5

relatively aggressive recycling program in the first place. This would account for the lower average decrease in tonnage landfilled, because residents would already have been taking measures to minimize MSW production and maximize materials diversion. Second, residents may respond hostilely to a mandatory program, feeling that participation in such a collective activity should be done on a strictly voluntary basis.

We do not have data on either of these two underlying ideological characteristics. Examining per capita waste generation and recycling levels prior to the introduction of unit pricing indicates that the first explanation may be plausible in at best two of the three very aggressive recycling program cities. In reality, this empirical anomaly is likely accounted for by some combination of the two explanations.

We also divided the cities according to the levels of the unit-based fees. The three cities with "high" fees (fee > $1.25) had an average decrease in tonnage landfilled of 41.3 percent; the 12 cities with "medium" fees ($1.25 > fee > $1.00) had an average decrease of 41.2 percent; and the 4 cities with "low" fees (fee < $1.00) had an average decrease of 47.5 percent. Contrary to our data results, economic theory would predict that high-fee cities should have a larger decrease in tonnage landfilled than low-fee cities. The average decreases in tonnage landfilled across levels of fees in our sample, however, are not statistically different from one another. This holds true even after controlling for the differences in per capita income across the sample.

In addition to grouping the cities according to type of pricing method, aggressiveness of the recycling program, and level of the unit-based fee, we tried to decompose the decrease in tonnage landfilled into its component parts. In order to reduce their tonnage landfilled, households could turn to materials diversion efforts, including recycling, composting, burning, and illegal disposal. They could also turn to source reduction efforts by changing consumption patterns, such as switching from disposable to reusable items, purchasing items in bulk or with reduced packaging, or perhaps reconditioning items that would have been thrown away. The question then becomes, how did each of these activities contribute to the decline in tonnage landfilled?

Table 5. Change in tonnage recycled in response to implementation of unit pricing.

Antigo, WI	+145%
Charlemont, MA	Not available
Downer's Grove, IL	Recycling program implemented simultaneously
Grundy Center, IA	Not available
Hancock, VT	Recycling program implemented simultaneously
Hartford, VT	+29%
Harvard, IL	+113%
High Bridge, NJ	+3% (questionable data)
Huntingburg, IN	Recycling program implemented simultaneously
Ilion, NY	+141%
Ithaca, NY	+63%
Lisle, IL	Recycling program implemented simultaneously
Mt. Pleasant, IA	Not available
Mt. Pleasant, MI	+141%
Perkasie, PA	+157%
Plains, PA	+88%
Quincy, IL	+45%
River Forest, IL	Recycling program implemented simultaneously
Saint Charles, IL	+456%
Weathersfield, VT	+150%
Woodstock, IL	Recycling program implemented simultaneously

Recycling

Increased recycling explains some of the decline. Table 5 documents the recycling experiences of the 21 cities studied. Of the 21 cities surveyed, 7 implemented recycling programs at the same time as the unit-pricing program, and 2 cities were unable to provide any recycling data. Of the remaining 12 cities, the average increase in tonnage recycled was 128 percent, with a high of 456 percent for St. Charles, Illinois, and a low of 3 percent for High Bridge, New Jersey. The High Bridge county recycling coordinator expressed skepticism about that city's small increase in recycling. The coordinator cites possible data discrepancies, including changes in commercial levels of recycling that may have occurred at the same time. If High Bridge is excluded from the data set, the average increase in recycling climbs to 139 percent.

In the 12 cities that operated recycling programs prior to adopting unit pricing, major increases in quantities recycled clearly occurred after switching to unit pricing. Mt. Pleasant, Michigan, increased its recycling tonnage by 141 percent without changing its curbside recycling program, and Ithaca, New York, continued its mandatory curbside program, yet increased tonnage by 63 percent. Ilion, New York, added recycling of two minor items—tin and white goods. After adjusting for these changes, recycling still increased 132 percent. Plains, Pennsylvania, which collected newspaper at curbside prior to adopting its pay-per-bag system, increased its newspaper tonnage recycled by 66 percent. Plains added glass pickup as well, contributing to an overall tonnage increase of 88 percent. The experiences of these four programs indicate that unit pricing alone causes large increases—from 63 to 141 percent in our data sample—in recycling levels.

Other cities that made more significant changes in recycling services offered at the same time that they switched to unit pricing still experienced larger recycling increases than would be expected if just the recycling program was enhanced. Antigo, Wisconsin, which increased curbside collection from once to twice a month, more than doubled its recycling rate with a 145 percent increase. Harvard, Illinois, and Perkasie, Pennsylvania, moved from partial to full curbside collection. These cities increased recycling by 113 percent and 156 percent, respectively. Overall, cities generally made minor changes to recycling programs that by themselves do not explain the large increases in recycling. Unit pricing appears to be responsible for a substantial portion of the increase.

Interestingly, the three communities with *mandatory* recycling programs increased their tonnage recycled by an average of 83 percent. This suggests that mandatory recycling does not motivate individuals to maximize the amount of materials diverted from the landfill, and solid waste officials do not aggressively pursue enforcement under such systems. Unit pricing may provide a financial incentive that is more effective in eliciting particular behaviors than command-and-control type government directives.

In a national survey of municipal experiences with recycling programs, David Folz [1991a, 1991b] of the University of Tennessee found that the mean waste stream diversion rate was 8.4 percent for cities that targeted only newspaper, glass, and aluminum. For cities that included plastics, corrugated paper, scrap metals, and high-grade paper (the four next most widely recycled items), the mean diversion rate was 16.6 percent. The overall mean diversion rate for voluntary curbside recycling programs was 12.3 percent, which is much lower than the 29 percent reported by the cities with curbside recycling and unit pricing covered by our sample. While the recycling increases are large, they do not account for the full reduction in total waste generated. Recycling increases accounted for as little as 1 percent (if you take the High Bridge data at face value) to as much as 68 percent of the total waste reduction. Clearly residents were doing more than just recycling in the presence of unit pricing.

Composting

Composting of yard waste may constitute a significant contributor to reduced tonnage landfilled. Few cities kept data on tonnage composted. For the three cities that did, composted material accounted for from 6 to 11 percent of the total waste stream—and from 8.9 to 36.5 percent of the reduction in waste landfilled. For the three cities that recorded this information, the data may not account for all yard waste diverted from landfill use, because some of it is left on lawns, composted in back yards, or burned in bonfires, legally or illegally. Franklin Associates [1990] estimate that yard waste accounts for 17.6 percent of the weight of municipal solid waste nationally. Yard waste diversion is likely to play a large role in Illinois cities, where yard waste has been banned from landfills.

Burning and Illegal Disposal

Burning trash contributed significantly to reductions in Antigo, Perkasie, and Plains. With paper comprising 40 percent of the waste stream [Franklin Associates, 1990], aggressive burning could explain all of the remaining unattributed reductions that occurred in these cities. However, when Perkasie banned burning in 1989, one year after adopting its unit pricing ordinance, it experienced only a 21 percent increase in landfill disposal over 1988. The increase of 20 tons per month represents less than 10 percent of the city's 1987 residential waste stream prior to adopting unit pricing. Thus, even when burning is legal, it appears to account for no more than 20 percent of waste reduction. Officials in the other cities studied said they were not aware of any increases in burning.

With a few exceptions, city officials all reported no noticeable increase in littering and said that illegal dumping was not a problem.

Measurement Error

Of course, some of the decrease in total waste generated could result from measurement error. To test this possibility, we constructed an alternative method for measuring the decrease in waste generated. Woodstock and Harvard, Illinois, are located in McHenry County, about 50 miles northwest of Chicago. While these two cities have per-bag pricing systems, they do not have before and after data on waste generation. McHenry County's Office of Recycling, however, commissioned a study on household waste generation that revealed interesting differences between McHenry County towns that have per-bag pricing and those that do not. GAS Consultants of Milwaukee, Wisconsin, took random samples of waste collected in single-family residential neighborhoods in six McHenry County towns: Woodstock, Harvard, Crystal Lake, Marengo, Cary, and McHenry.

By making the assumption that the six cities would have roughly equivalent waste generation under similar pricing and waste collection systems, we were able to take an alternative approach to estimating the effects of a per-bag pricing system. The towns of Woodstock and Harvard had both a recycling program and unit pricing; Crystal Lake and Marengo had a recycling program, but used a traditional flat fee for MSW collection services; and Cary and McHenry had neither a recycling program nor unit pricing.

The two towns with both recycling and unit pricing generated about 31 percent less waste per household than the two towns with neither.[3] In the two towns with both recycling and unit pricing, residents also generated about 18 percent less waste per household sent to landfills than residents in the two towns with a similar recycling program but no unit pricing. The two towns with recycling but no unit pricing generated 17 percent less waste per household sent to landfills than the two towns with neither program. Recycling programs alone resulted in 5.4 to 6 pounds per household being recycled. With price incentives and a recycling program, there was a 17–30 percent greater level of recycling in Harvard, at 7 pounds per week per household. In Woodstock, recycling levels were 65–83 percent higher, at 9.9 pounds per week per household.

The McHenry County data also substantiate the claim that once per-container charges are implemented, people stuff more waste into each container. The average container in Woodstock and Harvard weighed 21.7 pounds—23 percent more than the average container in the other four cities. This informa-

[3] Since the study was done, both Cary and McHenry have switched to per-bag systems. No follow-up study has been commissioned.

tion is relevant because many cities without before and after data on tonnage sent to landfills do have rough estimates of bags per household. For example, Harvard estimated that residents placed 3 to 4 bags curbside per household prior to implementation of the per-bag pricing system. The GAS study showed an average of 1.6 bags after adoption of the pricing system. If we conservatively estimate the previous per-bag weight at 15 pounds (the lowest average weight of containers in the other four cities studies), then each house previously put out 45–60 pounds per week. After the unit-based pricing program was put into place, households put out an average of 34.4 pounds per week per household. Under this estimation method, the Harvard reduction is 24–43 percent, with a mid-point estimate of 34 percent. This 34 percent reduction estimate fits closely with our previous reduction estimate of 31 percent. Thus, while there is measurement error in all data, we are reasonably confident that our data allows for reasonable estimates of changes in waste generation in response to the implementation of unit-pricing programs.

Source Reduction

We were unable to obtain quantitative data on the extent of illegal dumping, more careful purchasing, or stockpiling of trash. Newspaper articles reported anecdotally on individuals who said they responded to pricing programs by paying more attention to the volume of packaging on products. To what extent, then, did individuals use source reduction strategies to combat a rising waste disposal bill? Table 6 documents the reduction in total waste landfilled that can be explained by increases in recycling and composting activities.

If we assume that individuals compost 10% of the waste that they generate, then recycling and composting account for an average of 50.4% of the reduction in total waste landfilled, with a low of 21% and a high of 100%. If instead we assume that individuals compost 17% of the waste they generate (the maximum average amount determined by Franklin Associates [1990], then recycling and composting account for an average of 72.4% of the reduction in total waste landfilled, with a low of 36% and a high of 122%. Even under the 17% assumption, recycling and composting explain less than half the total reduction in waste landfilled in six cities—and it is unlikely that individuals are actually composting 17% of their waste stream. Even with 10–15 percent measurement error, individuals still seem to be undertaking significant source reduction activities. Thus even very aggressive recycling programs do not eliminate residents' desire/incentive to decrease MSW production through source reduction activities.

Long-Term Effects of Unit Pricing Programs

While most programs are so new that data were not available for more than a year following program adoption, five cities reported data for several years. Three of these—High Bridge, Ilion, and Perkasie—provided data for three years following program adoption. These cities' experiences show that initial reductions largely hold over time. Most of these cities experienced small increases in landfill waste disposal in the second year following adoption: an 8 percent increase in Ilion, a 4 percent increase in Plains, and a 21 percent increase in Perkasie. The larger increase in Perkasie can be attributed to

Table 6. Decomposing the reduction in total waste landfilled.

City	Percentage decrease in tonnage landfilled (A)	Proportion of (A) accounted for by recycling increase (%)	Proportion of (A) accounted for by composting increase (%) (10% assumption)	Proportion of (A) accounted for by composting increase (%) (17% assumption)	Unexplained decrease—due to measurement error and source reduction activities (%) (10% composting assumption)
Antigo, WI	50	19	21	36	60
Charlemont, MA	37	NA	27	46	73
Downer's Grove, IL	52	NA	NA	NA	NA
Grundy Center, IA	32	20	31	53	49
Hancock, VT	33	48	30	51	22
Hartford, VT	17	10	62	105	28
Harvard, IL	33	16	32	54	53
High Bridge, NJ	18	5	72	122	23
Huntingburg, IN	74	15	14	23	72
Ilion, NY	51	11	20	34	31
Ithaca, NY	31	25	36	61	39
Lisle, IL	53	NA	NA	NA	NA
Mt. Pleasant, IA	49	NA	21	36	79
Mt. Pleasant, MI	44	26	25	42	50
Perkasie, PA	54	32	21	35	48
Plains, PA	49	6	21	36	73
Quincy, IL	41	1	25	42	74
River Forest, IL	19	9	52	88	39
Saint Charles, IL	41	30	25	43	45
Weathersfield, VT	36	68	32	54	0
Woodstock, IL	31	NA	NA	NA	NA

population growth and a ban placed on backyard burning. In Ilion and Plains, population increases or refinement of data may also have contributed to the second-year increases. On the other hand, High Bridge and Ithaca experienced further reductions of 4 percent and 20 percent, respectively. Both of these decreases occurred after additional price increases.

While cities are extremely sensitive to an initial change from zero price to per container charges, responses to subsequent price changes are understandably less sensitive. In High Bridge, a 4 percent reduction in disposal occurred after a price increase from \$1.25 to \$1.65 per unit. Ithaca demonstrated a stronger response to a price increase, dropping 20 percent following a price change from \$0.83 to \$1.08 per bag.

In all five longer term cases, the second- and third-year landfill waste disposal rates remained well below preprogram levels. Landfill tonnage in Perkasie remained 36 percent below its pre–unit-pricing level of three years earlier. In Ilion, it was 40 percent lower three years later; in High Bridge it was 20 percent. Plains remained 47 percent lower two years later, and Ithaca was 45 percent lower. These cities exhibited similar staying power in their recycling increases over longer periods, with the exception of High Bridge. These results support the theory that unit pricing provides residents with a continuing incentive to decrease the quantity of waste conventionally disposed, increase recycling, and reduce the total amount of garbage produced.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Unit pricing provides residents with an incentive to source reduce and recycle by forcing them to pay the increased disposal cost for each additional unit of garbage. It thus represents a promising application of market-based incentives to environmental policy and management. In addition, unit-pricing programs may provide residents with a systematic reminder of their individual contributions to the local flow of solid waste—thus engendering more of a collective commitment to resolving solid waste management problems.

By implementing curbside recycling or by offering yard waste collection, communities make it easier for residents to divert their waste away from the landfill, without necessarily reducing the total amount of garbage generated. Consequently, running a recycling program in conjunction with a unit-pricing program runs the risk of dampening the source reduction incentive faced by individuals. The data from our 21-city sample, however, indicate that even in the presence of an aggressive recycling program, significant source reduction still occurs.

We were able to identify only one city that implemented unit pricing without a concurrent recycling program—Nanticoke, Pennsylvania. For a variety of reasons, this program proved to be an unmitigated failure. Residents quickly turned to private haulers for waste collection services, undercutting the municipality's revenue base; and city managers reported elevated levels of illegal dumping. Nanticoke eventually switched back to a traditional flat-fee system. While anecdotal, the Nanticoke example raises the possibility that complementarities may exist between materials diversion and source reduction activities. An aggressive recycling program may provide a transition path for communities—giving consumers time to alter purchasing and consumption patterns and giving companies time to market products packaged in a more environmentally sensitive manner.

In addition, recycling may help promote individual accountability for the environment by reminding people every time they recycle that their actions have an effect on the ecosystem. Recycling may offer people a chance to feel that they are making some positive contribution to the effort to protect the environment, and it may encourage them to extend their contributions beyond solid waste management.

Even if a community decides to offer curbside recycling, there are still many choices to make about the types of materials collected, who sorts them, who provides the containers to place them in, and so forth. Ultimately, the community will have to assess the trade-off between increased waste diversion and increased program costs. In fact, communities may want to consider charging a unit-based fee for collecting recyclables—presumably one that is lower than the unit-based fee for solid waste that is eventually landfilled.

A common criticism of programs structured like unit-pricing of MSW is that they are regressive in impact. Our data did not allow us to explore this question in any depth. Depending on the tax revenue base that served as the source of the traditional flat fee, unit-pricing costs may be partially offset by concomitant decreases in other local charges to households. Regardless, some communities are experimenting with unit prices differentiated by income levels—much like those in place for utilities.

While the wealth and income measures (housing values, educational attainment, and household income) for our 21-city sample are well above the national average, at least half the sample is below the national average. Thus the influence of community wealth and income on unit-pricing program outcomes is unclear. In addition, we were unable to determine whether racial composition is likely to influence the success of failure of a unit-pricing program. We were also unable to obtain information on the number of single-family versus multiple-family residences in our sample cities—a factor that can add considerable administrative and monitoring costs to unit-pricing programs. For a relatively small community that is evaluating the effects that unit-pricing and recycling programs might have on its solid waste flows, the averages reported in this study are reasonable estimates for changes in residential waste sent to the landfill and residential waste recycled. The actual levels observed will depend in part on what unit price the community charges and what type of recycling services it offers. In deciding whether to implement unit pricing, communities should be careful to tailor the program to demographic and waste generation characteristics within the broader context of an integrated solid waste management program.

While this article presents important evidence on the efficacy of unit-based pricing programs for residential municipal solid waste, our results are at best preliminary. Future research should develop a more sophisticated model of recycling options, explicitly examine cost trade-offs between materials diversion and source reduction activities, explore how demographic characteristics may contribute to the relative success of unit-pricing programs, investigate distributional impacts of unit-pricing programs, examine the impact of single-family versus multiple-family residences on program success, explore unit-pricing options for commercial MSW, and consider unit-pricing programs within the context of integrated solid waste management programs.

The authors wish to acknowledge Charles Clotfelter, Philip Cook, Gregory Duffee, James T. Hamilton, Timothy Jacobs, Helen Ladd, Sharon LaPalme, Jim Miller, Vijaya Ramachandran, and two anonymous reviewers for their insightful advice on this research project. All remaining errors are our own.

MARIE LYNN MIRANDA is Assistant Professor at the Sanford Institute of Public Policy, Duke University, Durham, North Carolina.

JESS W. EVERETT is Assistant Professor at the School of Civil Engineering and Environmental Science, University of Oklahoma.

DANIEL BLUME is a Program Examiner with the Office of Management and Budget.

BARBEAU A. ROY, Jr., is a consultant with Ernst and Young.

REFERENCES

Ademec, B. (1991), "Volume-Based Collection Fees: A Success Story," *Resource Recycling* 10(3), pp. 139–140.

Denison, Richard A. and John Ruston (1990), *Recycling and Incineration: Evaluating the Choices* (Washington, DC: Island Press).

Folz, David (1991a), "Recycling Program Design, Management and Participation: A National Survey of Municipal Experience," *Public Administration Review* 51(3) (May/June).

Folz, David (1991b), "Public Participation and Recycling Performance: Explaining Program Success," *Public Administration Review* 51(6) (November/December).

Franklin Associates (1990), *Characterization of Municipal Solid Waste in the United States, 1960 to 2010*. Report prepared for the United States Environmental Protection Agency, June.

Goldberg, D. (1990), "The Magic of Volume Reduction," *Waste Age* 19(2), pp. 98–104.

Menell, Peter S. (1990), "Beyond the Throwaway Society: An Incentive Approach to Regulating Municipal Solid Waste," *Ecology Law Quarterly* 17, pp. 655–740.

Minnesota Office of Waste Management (n.d.), "A Guide to Volume-Based Fees for Garbage Collection."

Office of Technology Transfer (1990), "Volume-Based Garbage Rates," *Solid Waste Management Newsletter* 4(5), pp. 1–3.

Platt, B., C. Doherty, A. Broughton, and D. Morris (1990), *Beyond 40%: Record Setting Recycling and Composting Programs. (Washington, DC: Institute for Local Self-Reliance).*

Riggle, David (1989), "Only Pay for What You Throw Away," *BioCycle* (February), pp. 39–41.

Skumatz, Lisa (1989a), "Variable Rates: Using Your Rate Structure to Encourage Waste Reduction and Recycling." Unpublished paper.

Skumatz, Lisa (1989b), "Volume-Based Garbage Rates: Your Best Recycling Program," *Resource Recovery* (October), pp. 5–7.

Skumatz, Lisa (1990), "The Buck Is Mightier Than the Can," *BioCycle* (January), pp. 40–42.

Skumatz, Lisa and Philip Zach (1993), "Community Adoption of Variable Rates: An Update," *Resource Recycling* 11(6), pp. 68–75.

Sproule, Kimberly and Jeanne Cosulich (1988), "Higher Recovery Rates: The Answer's in the Bag," *Resource Recycling* (November/December), pp. 20–21+.

Stavins, Robert N., et al. (1988), *Project 88: Harnessing Market Forces to Protect Our Environment*. Washington, DC.

Stavins, Robert N., et al. (1992), *Project 88 Update*. Washington, DC.

U.S. Environmental Protection Agency (1990), *Characterization of Municipal Solid Waste in the United States: 1990 Update*. EPA/530-SW-90-042A, June.