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THE LEARNING CURVE'S ROLE IN EXPLAINING HOUSEHOLD CURBSIDE RECYCLING RATES

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ABSTRACT

This article asserts that the average household needs time to learn how to recycle common household materials once a recycling program has been put into place by the local municipality. Households must learn to sort waste efficiently and develop good recycling habits. This means learning when to recycle, what to recycle, and how to recycle. After these skills are learned the skills then need to be incorporated into the daily lifestyle of household members. The article tests this assertion by running an autoregressive model with household recycling as the dependent variable and recycling "lagged" as independent variables. Other independent variables which are common to the literature, such as education and community tenure, are used within the model as well. Monthly data was collected from waste disposal authorities during their first few months of operating a recycling program. The results presented in this article can enhance planning by community officials who are considering starting their own recycling programs. It will give them an idea as to how much time is needed before households become adept at recycling. Community officials can then better plan for the growth as they experience their own learning curve when dealing with the relatively new community service (i.e., collecting and marketing recycled products).

1) INTRODUCTION

Recycling per household has grown tremendously since the 1960s. For example, annual recycling per capita was 62.05 pounds per person in 1960, or 5% of the

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generation of municipal solid waste (MSW). By 1970, annual recycling rates were 80.3 pounds per person. Then, as more communities started their own curbside recycling programs, the amount of recycling per capita jumped to 127.75 pounds per capita in 1980. There are currently over 9,000 cities that provide curbside pickup of recycled materials in America compared to just a handful of cities providing curbside pickup in the 1970s [1]. By 1990, Americans were recycling 266.45 pounds per person annually. By 2000 the growth had increased dramatically to 492.75 pounds per person. Although we are recycling more than ever, we can do better. Currently, Americans only recycle 32.1% of their MSW [2].

In general, society regards recycling as a commendable practice which yields numerous benefits. Recycling materials does take energy and other inputs to convert the recycled material back into reusable form. In many cases the energy required to process a recycled material back into a reusable form is less than that used in producing a new item from virgin materials; in other cases it is more. Recycling is also thought to help conserve natural resources and reduce resource extraction while saving on landfill space, which helps alleviate the environmental problems associated with those activities.

As an example of the environmental benefits received from making products with recycled materials versus those from producing products from virgin source materials, consider that one ton of recycled paper is said to save 17 trees from being harvested and create 95% less air pollution while using 60% less energy. One ton of glass made from 50% recycled materials avoids 250 lbs. of mining waste, creates 20% less air pollution and 50% less water pollution, and uses 50% less energy. According to some calculations, one ton of recycled steel prevents 2,500 lbs. of ore, 1,000 lbs. of coal, and 40 lbs. of limestone from being mined. Finally, one ton of recycled aluminum reduces bauxite mining by 8,000 tons and creates 95% less pollution while consuming 95% less energy [3].

Along with the environmental benefits, the recycling and reuse industry has become a very prominent component of the United States economy, contributing 2.7% to the overall US GDP. Today there are over 56,000 private and public recycling and reuse enterprises in America. These enterprises range from recycling collectors and processors to recycling/reuse manufacturers. This industry as a whole employs 1.1 million people, almost as many as the manufacturers in any of the machinery, auto and trucking, food, and computer and electronic industries. The recycling and reuse industry generates a payroll of $37 billion with receipts topping $236 billion. Employment growth within the recycling and reuse industry was estimated at 8.3% from 1967 to 2000, while the rest of the U.S. employment grew at a rate of 2.1% during the same time period [4]. These estimates include recycled materials from residential household waste of both durable and non-durable goods as well as commercial waste. Materials range from ordinary household and commercial paper products to computers to steel and other metal waste material.

There are four main sectors in the recycling and reuse industry: collectors, processors (sorters of the recycled materials), recycling manufacturers, and reuse manufacturers. Although there are more enterprises in the collection and processing sector, these enterprises tend to be much smaller in scale, generating less revenue and employing less people than do the recycling and reuse manufacturers. The recycling and reuse manufacturing sectors require a more highly skilled worker than the collection and processing sectors and therefore pay higher wages. Wages in the recycling and reuse manufacturing sector are above the national average. Of the 1.1 million people employed in the recycling and reuse industry, 80% are employed in the recycling and reuse manufacturing sector. The recycling and reuse manufacturers are considered downstream industries and the collection and processing firms are considered upstream industries [4].

Once confined to local markets, recycling has expanded into a truly international market. From 1970 to 1997, the combined total of recycled trade in aluminum, lead, zinc, copper, and paper increased nearly 10-fold from 2.5 million tons to 21.5 million tons [5]. Secondary iron and steel scrap has increased from 20 million tons to 37 million tons during the same period. Much of the international trade is the direct result of a thirst by developing countries for cheap raw materials. Virgin raw materials are hard to come by in these economies and the developed economies have an ample supply (if not an oversupply) of cheap recycled materials. Therefore, most trade in recycled goods on the international market flow from developed to developing nations. The international recycling trade currently surpasses the "development of agricultural and consumer product markets" [5].

There is a lot of academic literature on recycling, especially on searches for variables that might be instrumental in explaining how and why households recycle and in determining the amount of material that households will recycle. This article attempts to enhance the existing body of literature by exploring how "adaptive behavior" affects the amount of solid waste that households recycle. The emphasis in this article is that recycling takes time and effort on the part of common households. Typically, there is an overall resistance to cooperate at first; however, once households get into the habit of sorting their recyclables, recycling becomes a part of their daily lifestyle. At first it takes time for consumers to learn how to sort, clean, and recycle their waste efficiently. However, as with many other repetitive tasks, the more they recycle the better they become at this process. As the consumer moves along the learning curve of recycling, their marginal time per unit of recycled material decreases. This type of psychological inertia to change causes a lag effect in the amount of waste that gets recycled. Indeed, researchers Taylor and Todd [6] find that households view recycling as a complex activity, but just as with most activities, the more experience they have with recycling, the role of complexity decreases in a household's decision to engage in recycling. Not only do households need time to develop good recycling habits, but municipalities, too need time to develop and practice

their own systems for handling recycled waste and finding new markets and customers for the recycled materials.

Since it takes households time to learn to recycle, then it follows that current recycling rates are a function of prior, or lagged, recycling rates. The purpose of this article is to identify how long of a lag it takes for households to develop good recycling habits. First, the literature concerning other variables that help determine recycling rates is reviewed. The statistical model used to test the article's premise is then presented followed by a discussion of the data set. Lastly, test results are discussed and implications are drawn.

Literature Review

In general, the literature on recycling understands that recycling is an activity that takes time and effort on the part of households. Economics literature points out that the higher the income of an individual, the higher the opportunity cost of time; therefore, in theory it is more costly (in terms of time) for high wage individuals to engage in recycling. If it is costly, then why do households engage in recycling? Research shows that households will engage in recycling if they know how to recycle. This requires education and instruction for households on the part of municipalities. Households will also engage in recycling if they are environmentally aware and they place a high priority on a clean environment. Households might also engage in recycling if they think there is a financial reward to recycling. They could save money either directly or indirectly, by having lower waste disposal fees or being paid directly for any recycled material they generate. In short, households will engage in recycling if: a) they know how, b) they are environmentally concerned, and c) if there is a financial reward for recycling.

Research by Saltzman, Duggal, and Williams [7] demonstrates how the opportunity cost (or value of) time affects the amount of recycling engaged by households. They use comparative statics from their theoretical model to sign the coefficient of opportunity cost (or income) on recycling. It turns out to be negative, a tendency predominant in most other research. However, in their research they found that the coefficient on income for recycling is positive for newspapers, which are relatively easy to sort, but negative with respect to those items that take longer to sort, such as beverage containers (sorted by plastic, cardboard, green glass, brown glass, and clear glass).

Hong, Adams, and Love [8] conducted a large survey of Portland, Oregon households in order to investigate the role that price incentives and other socio-economic variables have in determining household recycling participation. They found that as the value of time increases, curbside recycling participation decreases. In addition, they find that a unit increase in waste disposal fees increase the probability of frequent recycling. They also find that both education and household size are positively related to increases in recycling participation rates, and they further find that non-whites and rental households participate less in curbside recycling.

In a cross sectional study that compares communities with waste disposal fees to communities without the disposal fees but with or without a curbside collection program, Kinnaman and Fullerton [9] find that a per-unit fee for waste disposal, without correction for endogenous policy, has a positive cross-price effect on recycling. However, they also write that when the endogenous policy is corrected for, the cross-price effect on recycling disappears. They summarize that a per-bag fee for waste disposal helps reduce the generation of household solid waste and provides an incentive to recycle. They find that implementation of a curbside household recycling program (and without the disposal fee) generates 192.91 lbs. per person of recycled material. They also find that retirees, college graduates, and homeowners tend to recycle more than their counterparts and that a "bag and tag" method of charging for waste disposal is more effective at generating recycling than a subscription based program.

Thogersen [10] surveys 1,955 households from 8 different Belgian municipalities (5 municipalities with a fee-based waste collection system and 3 with a fixed-fee waste collection system) and finds that a fee-based waste collection system does indeed increase curbside recycling. However, Thogersen argues that the increase in recycling is not all attributable to the "price-effect" of the monetary incentive but that rather the price effect stimulates perceived self-efficacy (i.e., stimulates trial and experimentation in recycling) and personal norms. One possible explanation for this is that the monetary incentive inherent in the fee-based collection system is too small to stimulate a great deal of recycling through a price effect. Instead he finds that both the self-efficacy and personal-norms effect explain most of the increase in recycling.

Rankin reports on the results of a telephone survey conducted by the Massachusetts Department of Environmental Protection concerning recycling behavior and attitudes [11]. Some 750 Massachusetts residents participated. The survey revealed that: a) long-term residents have higher recycling participation rates than short-term residents, b) communities with newer recycling programs have lower participation rates than communities with a well established recycling program, and c) single family dwellings are more likely to recycle more than households residing in apartments. These three findings bear witness that recycling is a learned behavior that requires time to adjust and adapt. Rankin suggests that in order to increase recycling, the state needs to simplify local recycling programs with clear and easily accessible instructions for recycling. In addition, local programs throughout the state need to be standardized. These two practices would help improve recycling rates when a resident moves from one community to another, he would not have to readjust to the local recycling practices which are unique to any one specific Massachusetts community. Other findings from the survey show that income and education are not strong predictors of recycling behavior but that the age of the resident is. Those over 65 years of age are more likely to participate in recycling than those under 35 years of age. It could be that residents over 65 years of age have a longer tenure in their current

residence than those under the age of 35. Finally, the survey finds that those residents who live in a "pay as you throw" community have higher recycling participation rates and find recycling easier than those residents who don't reside in a "pay as you throw" community.

A survey of 700 city residents (population 120,000) conducted by Taylor and Todd [6] found that the city's recycling and composting programs were equally complex yet more residents participated in the recycling program than in the composting program (93% versus 62%). The authors suggest that the reason for the disparity is simply that the recycling program was in place longer than the composting program (2 years). Survey participants simply had more time to learn and solidify recycling behaviors than composting behaviors. The authors conclude, "With increased experience, the negative influences of complexity may be overcome. This suggests that efforts should be made to reduce complexity early in the diffusion of an environmental program, but that the importance of complexity as a determinant of attitude may diminish over time" [6, p. 19].

The attitudes that residents have concerning the environment also play a role in recycling. For instance, De Young [12] surveyed 107 Ann Arbor, Michigan residents in order to determine their motivation for adopting environmentally-friendly behaviors, such as recycling and reuse. He fond that residents derive satisfaction from being frugal and from participating in an activity that has a positive impact on their community.

In another survey of 673 Toronto-area residents, Scott [13] found that 40% of the respondents claimed their main motivation to recycle was a general concern for the environment, especially by conserving natural resources and minimizing impacts of resource extraction. Thirty-three percent of the respondents stated that their main motivation to recycle was to save on landfill space which would "minimize the need to build more landfills."

Johnson, Bowker, and Cordell [14] found from a survey of 3,513 residents that there is ethnic variation with respect to recycling. Whites and Asians are almost twice as likely to recycle on a regular basis as Blacks and foreign-born Hispanics. They also learned that U.S.-born Hispanics are more likely than both Blacks and foreign-born Hispanics to recycle on a regular basis. They found that women, the elderly, urban dwellers, large families, liberals, and persons with post-secondary education, are all more likely than their counterparts to participate in regular recycling.

Martinez and Scicchitano [15] surveyed, by telephone, 1,020 residents from different Florida communities about their recycling participation rates and attitudes toward recycling. Each community had used varying media to educate and inform residents about the local recycling program. Martinez and Scicchitano learned that public-service media campaigns informing citizens about community-based recycling programs are effective at increasing recycling rates, but only for highly-educated individuals and not for poorly-educated individuals.

It appears that higher-educated persons are more receptive to civic-minded messages, in general. Public media campaigns promoting recycling do very little, if anything at all, to stimulate recycling among less-well-educated populations. But, for the general population with some college education, media efforts informing the public about recycling turn out to be very effective in increasing recycling rates.

In short, the variables that are commonly found in the literature which affect recycling rates are: per-bag or per-lb. waste disposal fees, education, concern for the environment, household size, ethnicity, home ownership vs. rental, retirement, long-term residence, urban vs. rural residence, sex, and well-established recycling programs. Surprisingly, household income has been found in the literature negatively to affect recycling rates.

3) TEST DATA AND DESIGN

To test this article's assertion, data was collected from more than 50 municipalities, boroughs, and townships from the eastern half of Pennsylvania. In 1988, Pennsylvania passed Act 101 which requires municipalities, depending on their population density, to begin curbside recycling programs. What is especially instructive about this data set is that the municipalities provided month-by-month curbside collection data from their first two years of curbside collections. For purposes of this study, it was important to gather data from the initial startup periods of the program in order to detect the existence of a recycling learning curve. Unfortunately the municipalities could not provide week by week data. In addition, because the recycling program was new to many municipalities, many of them did not separate their data into different types of recycled material collected during the early years of operations.

Many of the municipalities put their curbside collections program into place shortly after the passage of Act 101. Other municipalities started up their curbside collection program later, depending on exactly when they fell under the purview of Act 101. For purposes of testing the hypothesis laid out in this article, it doesn't matter when the program started, as long as data from the first few months of operations were provided.

The following autoregressive model is used to test the hypothesis:

$$R = a + b_1R_{t-1} + b_2R_{t-2} + b_3T + b_4G + b_5W + b_6A + b_7E + b_6P$$

where:

R = recycling per month per household in lbs.
R_{t-1} = recycling per month per household in lbs.—one month lagged
R_{t-2} = recycling per household per month in lbs.—two months lagged
T (tenure) = % of the community that are renters (vs. home-owners)
G (graduate) = % of population within the community with a graduate or professional degree

W (white) = % of population within the community that is white
A (Asian) = % of population within the community that is Asian
E (elderly) = % of the population within the community that is over 65 years of age
P (population) = number of residents living within the community

The auto-regressive equation follows the classical learning curve models (or experience curve models) found in the economics literature. In these models, productivity or output, as well as per-unit cost reduction, is used as a dependent variable with cumulative output as an explanatory output. It is assumed that cumulative output is a good proxy for the learning effect. In this model, since the data is from the beginning of the curbside collection program, the lagged dependent variables actually represent the cumulative output that is inherent in the classical learning models. Arrow [16] writes that output depends heavily on knowledge and that "knowledge has to be acquired." He argues that "learning is a product of experience" and is acquired through repetition, and actually uses cumulative gross investment as a proxy for the learning effect. Day and Montgomery [17] define learning as that which "encompasses the increasing efficiency of all aspects of labor input as a result of practice and the exercise of ingenuity, skill and increased dexterity in repetitive activities." Hippel and Tyre [18] conclude from an empirical study of identification through field use of problems affecting "novel process machines" that "doing is sometimes the only practical way to succeed," attesting to the effectiveness of past experiences in moving along the learning curve.

From the literature review encapsulated within this article there is strong evidence to suggest that recycling is a learned behavior. As noted, the explanatory variables shown to have an impact on household recycling include homeowner vs. apartment-dweller, age, long-term tenure, and length of time that a community-based recycling program has been in effect. One can make the case that these variables actually make good proxies for the learning curve effect because they reflect how much time the homeowner has been exposed to the recycling program. For instance, apartment dwellers tend to have shorter tenure within a community and thus have to continually readjust to the recycling rules of new communities. On the other hand, homeowners tend to have longer tenure time within the community and have already learned how the recycling process works within the community. Age would be another example of a proxy for the learning curve effect. Elderly residents do not move as often as younger residents and, therefore, they are more likely to have already learned how recycling works within their community. The same could be said for variables that measure the long-term tenure of residents as well as how long the recycling program has been in effect. Since urban vs. rural populations was found to be a determining factor of recycling rates in previous literature, population is used in this model as a proxy for the degree of urbanization within the data set.

4) TEST RESULTS

The regression model from the preceding section was run using generalized least squares as opposed to ordinary least squares to minimize any possible effects that occur from autocorrelation. The results of the regression were reported in Table 1.

As the results from Table 1 shows, the model is a very good fit with an R^2 value of .9150. The regression results also show that the first two months of recycling positively and significantly impact the third month of recycling. This suggests that recycling is a learned behavior and that it does take time for households to overcome the initial inertia to change and to learn to adopt recycling habits into their daily household activities. What is encouraging is that households seem to adopt recycling practices into their daily lifestyles rather quickly. The results show that it only takes two months for households to get the hang of recycling and become proficient at the task. This should be encouraging news to municipalities that are thinking of starting up their own recycling programs in an effort to reduce landfill waste and costs, or to capitalize on any profits to be made from recycled material.

When the regression was run with the fourth month of recycling as the dependent variable and the first three months as independent variables, the first and third month were found to be insignificant.

The other variables that turned out significant were renters, graduate, elderly, and population. The percentage of renters in a municipality is negatively related to the amount of recycling as would be expected from the literature survey. Another explanation for the negative value on the coefficient is that apartment

Table 1. Total Recycled Materials as Dependent Variable

Variable	Coefficient	*p*-Value
Intercept	4.5796	.8531
Recycling lagged 1 period	.4603	.0009
Recycling lagged 2 periods	.3141	.0239
Renters	–37.2617	.0206
Graduate	45.9040	<.0001
White	–11.5654	.6438
Asian	85.5430	.2102
Elderly	55.4652	.0073
Population	.000116	.0252
$R^2 = .9150$		

buildings might contract out their removal of waste and recycled material with a private hauler and thus their recycled numbers do not get added into the municipalities' total. The proxy for education, i.e., the percent of residents who possessed a graduate degree, was positive and significant. However, when the percent of college graduates within a municipality was used as a proxy for education, the variable turned out insignificant and negative, contrary to what has been shown in prior research. Elderly and population also turned out to be positively related to the amount of curbside recycling within a community, as was expected from the literature review. The regression model was then run on just the amount of recycled newspaper within the community. The results are displayed in Table 2.

The results from Table 2 show that, unlike the first regression, where two lagged months were significant in explaining the third month of recycling, only the first month of recycling was significant in explaining the second month of newspaper recycling. The first two months of newspaper recycling were not significant in explaining the third month of newspaper recycling. These results make intuitive sense since recycling of newspaper is an easier and less time-intensive task than recycling of other materials. This result supports the work of Saltzman, Duggal, and Williams [7] in which they suggest that newspaper is relatively easier to sort than most other recyclable materials. What this demonstrates is that when municipalities start a curbside collection operation, they can expect to see a larger percentage of recycled newspaper at first and within a month the residents will have become proficient at recycling newspapers.

Table 2. Recycled Newspapers as the Dependent Variable[a]

Variable	Coefficient	*p*-Value
Intercept	27.8826	.0774
Recycling lagged 1 period	.6724	<.0001
Renters	12.7804	.4978
Graduate	11.8555	.0922
White	–37.2541	.0237
Asian	–23.7611	.7433
Elderly	8.2323	.6104
Population	.0000338	.3197
Income	.000183	.0570
$R^2 = .8917$		

[a]Total number of observations fell from 50 to 36 since not all municipalities could provide collection data that was separated by type of material.

Household income was not included in the first regression because it was found to be insignificant for explaining recycling rates by several researchers. Household income was included as a dependent variable in the second regression due to the fact that Saltzman, Duggal, and Williams [7] had reported it as significant in explaining newspaper recycling rates. Table 2 reports household income as being positive and significant in determining recycling rates of newspaper. Graduate, the proxy for education, was again found to be positive and significant.

Some of the other socio-economic variables that were reported as significant with the first regression became insignificant with the second regression. These variables are renters, elderly, and population. The explanatory factor of Asian, which is used to account for ethnic differences in recycling rates, remained insignificant. But, white turned from insignificant in the first regression to significant in the second regression. However, the coefficient on white was negative while all other previous research shows it as being significant and positive.

A third regression was run was on all other recycled material except newspaper. The results for this regression are shown in Table 3.

The regression shows that the model is a very good fit at explaining all other recycled materials with an R^2 of .9611. In addition, this regression is consistent with the first regression in the fact that the first two months are both significant at explaining the total amount of recycling of all other material in the third period. These results make sense in that they show it takes just about one month longer for residents to learn how to efficiently recycle all of their other materials, in contrast to newspaper recycling.

Table 3. All Other Recycled Materials (Except Newspapers) as Dependent Variable

Variable	Coefficient	*p*-Value
Intercept	2.3127	.7719
All other lagged 1 period	.4630	.0034
All other lagged 2 periods	.2891	.0081
Renters	–8.72	.2576
Graduate	20.50	<.0001
White	–4.06	.6224
Asian	–9.12	.7837
Elderly	11.56	.2043
Population	.000055	.0041
R^2 = .9611		

Two explanatory variables that were significant in the first regression were insignificant in the third regression: renters and elderly. However, graduate continued to be both positive and significant as well as population. The two explanatory variables that were meant to capture ethnic differences in recycling continued to be insignificant, contrary to what has been reported in previous studies.

Finally, it might be that some households master the recycling learning curve in a shorter period of time because they have a greater concern for the environment and hence, they are more motivated to recycle. It has generally been assumed that one of the more prominent predictors of household environmental awareness is educational attainment. To see if some municipalities master the recycling learning curve faster than others, two additional regressions were run. The first of these regressions was run from the same data set as in Table 1, but the 15 municipalities with the highest level of educational attainment (based on the percent of graduate or professional degree) were dropped. Then the regression was run once more, but this time the 15 municipalities with the lowest level of educational attainment (based on the percent of graduate or professional degree) were dropped from the data set. The results are displayed in Table 4.

As shown in Table 4, those municipalities that have a lower level of educational attainment (based on the percent of population who have obtained a graduate or professional degree) take two months, on average, to become proficient at recycling common household material. On the other hand, for those municipalities that have a higher level of educational attainment, the second month is insignificant. For these municipalities it takes only one month to become proficient at recycling. Therefore, if educational attainment can be thought of as a proxy for environmental concern, then it is fair to say that some municipalities can master the recycling learning curve faster due to a greater degree of environmental concern because they are more motivated to recycle than others.

The regression was run again with the second month as the dependent variable and only 1 month lagged as a dependent variable as well as the other independent variables. It was found that the first month of recycling was a significant predictor of the second month of recycling.

5) CONCLUSION AND INTERPRETATION

This article asserts that household curbside recycling is a learned behavior that requires time and effort on the part of household residents to become proficient at recycling. Households must overcome a learning curve and psychological inertia to change as they adopt recycling as part of their everyday household chores. To test this assertion, data was gathered from 50 different municipalities within Eastern Pennsylvania. The data set is unique in the fact that the municipalities provided month-to-month curbside collection data from their first two years of operations.

Table 4. Total Recycled Materials as Dependent Variable

Variable	Lower level of educational attainment coefficient	Lower level of educational attainment *p*-value	Higher level of educational attainment coefficient	Higher level of educational attainment *p*-value
Intercept	.5192	.9815	1.4287	.9671
Recycling lagged 1 period	.2917	.0646	.5065	.0071
Recycling lagged 2 periods	.6426	.0043	.2567	.1393
Renters	−21.6964	.2294	−39.8971	.0538
Graduate	98.6798	.0723	47.8996	.0059
White	−4.8713	.8293	−8.8438	.7940
Asian	−13.6416	.8441	89.0880	.3940
Elderly	10.2071	.6229	58.0616	.0253
Population	.000143	.0220	.00133	.7995
R^2 = .8352		R^2 = .9058		

A number of different regressions were run against the data using generalized least squares. The first regression had total recycled materials regressed against lagged dependent variables along with other standard explanatory variables. The data was then subdivided into two groups of recycled materials: a) recycled newspaper and b) all other recycled materials (with newspaper factored out). Regressions were then run against the two groups similar in format to the first regression equation. Finally, the data set was again segmented into two different groups based on the average level of graduate (or professional) degree attainment. Regressions were also run on these two groups as well.

The regression model used in this article was analogous to those found in the "learning by doing" or experience curves literature. Typically, in these models output (in this case recycled material) for a selected period or cost per unit is regressed against cumulative output. In this article total recycling is regressed against all relevant prior recycling periods, which actually represents cumulative output.

The test results show that recycling is truly dependent on lagged periods of recycling. It is somewhat comforting to know that the results indicate that for most recycled material (discounting newspaper), it takes an average household about two months to become proficient at recycling. This is a rapid turnaround time. Furthermore, it takes households slightly less time (about 1 month) to become proficient at recycling newspaper. The fact that the tests results indicate that there is a short learning curve associated with household recycling could be due to the fact that households are enthusiastic about recycling and want to be engaged in the process.

The test results also indicate that populations in municipalities where there is a higher percent of graduate or professional degrees master the recycling curve faster. This is attributed to the fact that households with higher levels of educational attainment might be more environmentally concerned and, therefore, might be more motivated to recycle.

As more municipalities grow and come into compliance with their own recycling mandates, they should be encouraged by these results. Municipalities can expect residents to quickly adapt to the recycling process and enthusiastically embrace the recycling program. This will allow municipalities to capitalize on reduced landfill waste and costs plus any profits that can be made in the recycled markets.

REFERENCES

1. Institute for Local Self-Reliance, *The New Recycling Movement: Part I, Recycling Changes to Meet New Challenges,* ILSR, Washington, DC, 2003.
2. U.S. Environmental Protection Agency, *Municipal Solid Waste in the United States: 2005 Facts and Figures,* EPA Office of Solid Waste, Report # EPA 530-R-06-011, Washington, DC, 2006.
3. University of Massachusetts, Amherst, Office of Waste Management, 2006. www.umass.edu/recycle/recycling_benefits.shtml

4. U.S. Environmental Protection Agency, *U.S. Recycling Economics Information Study,* R. W. Beck Inc., U.S. Recycling Economic Information Study: Prepared for The National Recycling Coalition, July 2001. Retrieved from www.EPA.gov/jtr/econ/rei-rw
5. P. Van Beukering, *Recycling, International Trade, and the Environment: An Empirical Analysis,* Kluwer Academic Publishers, Boston, Massachusetts, 2001.
6. S. Taylor and P. Todd, P., An Integrated Model of Waste Management Behavior: A Test of Household Recycling and Composting Intentions, *Environment and Behavior, 27*:5, pp. 603-630, September 1995.
7. C. Saltzman, V. Duggal, and M. Williams, Income and Recycling Effort: A Maximization Problem, *Energy Economics, 15*:1, pp. 33-38, January 1993.
8. S. Hong, R. Adams, and A. H. Love, An Economic Analysis of Household Recycling: The Case of Portland, Oregon, *Journal of Environmental Economics and Management, 28*:2, pp. 136-146, September 1995.
9. T. Kinnaman and D. Fullerton, *Garbage and Recycling in Communities with Curbside Recycling and Unit Based Pricing,* National Bureau of Economic Research, Inc., Working Paper Series #6021, April 1997.
10. J. Thogersen, Monetary Incentives and Recycling: Behavioural and Psychological Reactions to a Performance-Dependent Garbage Fee, *Journal of Consumer Policy, 26*:2, pp. 197-228, 2003.
11. K. Rankin, Massachusetts DEP Recycling Participation Survey, accessed June 2000 at: www.mass.gov/dep/recycle/reduce/stasrv00.doc
12. R. De Young, Some Psychological Aspects of Recycling: The Structure of Conservation Satisfaction, *Environment and Behavior, 18*:4, pp. 435-449, July 1986.
13. D. Scott, Equal Opportunity, Unequal Results: Determinants of Household Recycling Intensity, *Environment and Behavior, 31*:2, pp. 267-290, March 1999.
14. C. Johnson, J. M. Bowker, and K. Cordell, Ethnic Variation in Environmental Belief and Behavior: An Examination of the New Ecological Paradigm in a Social Psychological Context, *Environment and Behavior, 36*:2, pp. 157-186, March 2004.
15. M. D. Martinez and M. J. Scicchitano, Who Listens to Trash Talk? Education and Public Media Effects on Recycling Behavior, *Social Science Quarterly, 79*:2, pp. 287-298, 1998.
16. K. Arrow, The Economic Implications of Learning by Doing, *The Review of Economic Studies, 29*:3, pp. 155-173, 1962.
17. G. Day and D. Montgomery, Diagnosing the Experience Curve, *Journal of Marketing, 47*:2, pp. 44-58, Spring 1983.
18. E. Von Hippel and M. Tyre, How "Learning by Doing" is Done: Problem Identification in Novel Process Equipment, *Research Policy, 241*, pp. 1-12, 1995.

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