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ANALYSES OF RECYCLING BEHAVIOR, RECYCLING
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PROMOTING RECYCLING

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SHAUFIQUE FAHMI SIDIQUE

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ANALYSES OF RECYCLING BEHAVIOR, RECYCLING DEMAND, AND EFFECTIVENESS OF POLICIES PROMOTING RECYCLING

By

Shaufique Fahmi Sidique

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ABSTRACT

ANALYSES OF RECYCLING BEHAVIOR, RECYCLING DEMAND, AND EFFECTIVENESS OF POLICIES PROMOTING RECYCLING

By

Shaufique Fahmi Sidique

This dissertation analyzes the behaviors of recyclers, the demand for drop-off recycling and the effectiveness of policies promoting recycling. The first two essays in this dissertation are based on a survey of drop-off recyclers in the Lansing area in Michigan. The first essay studies the profile of people who utilize drop-off recycling sites and analyzes the factors influencing their site usage. The results show that the usage of drop-off recycling sites is influenced by demographic factors such as age, education, income and household size. Attitudinal factors are also found to affect site usage. Recyclers tend to use the drop-off sites more when they feel that recycling is a convenient activity and when they are more familiar with the sites.

The second essay examines the demand for drop-off recycling sites as a function of travel costs and various site characteristics using the random utility model (RUM). The findings of this essay indicate that increased travel costs significantly reduce the frequency of visits to drop-off sites implying that the usage pattern of a site is influenced by its location relative to where people live. This essay also demonstrate that site specific characteristics such as hours of operation, the number of recyclables accepted, acceptance of commingled

recyclables, and acceptance of yardwaste affect the frequency of visits to drop-off sites.

The third essay addresses recycling rates. The effect of various recycling and waste management policy variables on recycling rate is assessed by utilizing a county level panel data from Minnesota. Our estimation procedure takes into account the potential endogeneity of these policy variables. The findings of this essay suggest that variable pricing of waste disposal increases the rate of recycling. Other policy variables such as the enactment of recycling ordinances and cumulative expenditures on recycling education are also found to be effective measures to increase recycling rate.

To my beloved wife Husnita and my sons, Iman and Ihsan

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Recycling and municipal solid waste management are important environmental issues. Two hundred and fifty one million tons of municipal solid waste were generated in the United States in 2006 as compared to only 88 million tons in 1960 (USEPA, 2006). Concerns over this rising trend and increasing economic and social costs have prompted regulators and policymakers to introduce various policy initiatives aimed at reducing waste and increasing the amount of recycling. Among the policies and programs introduced are curbside recycling, drop-off recycling, source reduction efforts, recycling and waste legislation, and public education and campaign on recycling. Given the broad range of programs and policies available, there is a need to analyze the effectiveness of these practices. This dissertation contributes to recycling and waste management research by analyzing recycling behavior, demand and the effectiveness of several commonly adopted recycling policies and programs.

The first and the second essay in this dissertation attempt to bridge the gap in the recycling and waste management research by studying drop-off recycling. Relative to curbside recycling research, there are a limited number of studies on drop-off recycling. The first essay analyzes the profile of recyclers utilizing drop-off recycling centers. This essay examines the relationships between drop-off recycling site visits and the socioeconomic and demographic characteristics of drop-off recyclers. This essay also examines behavioral aspects that influence drop-off site visits. The findings enhance understanding of the factors influencing participation and usage of recycling sites among drop-off recyclers.

The second essay analyzes the demand for drop-off recycling sites in an urban area using the random utility model (RUM). The RUM model has been more commonly used in travel and recreation demand studies, and the essay is the first to apply the RUM method to assessing the demand for drop-off sites. The impact of different recycling site characteristics on the usage of drop-off sites is examined using the estimated model. The results from this essay provide policymakers a better understanding of the site characteristics that may influence the demand for drop-off recycling. The findings can also be used by policymakers and waste management companies to design, locate, and establish drop-off sites to increase site visits and collection of recyclables.

The third essay analyzes the effectiveness of various recycling and waste management policy variables on recycling rate. This essay utilizes county level panel data from Minnesota covering the year 1996 to 2004. The policy variables examined include variable pricing for waste disposal, expenditure on recycling education, provision of curbside recycling services and drop-off centers, and enactment of recycling ordinances. This study accounts for the cumulative effects of the expenditure variable on recycling rate and also investigates whether different recycling programs such as curbside and drop-off recycling act as complements or substitutes in increasing recycling rates. This study also examines the effect of income and demographic characteristics on recycling rate.

ESSAY 1. THE EFFECTS OF BEHAVIORS AND ATTITUDES ON DROP-OFF RECYCLING ACTIVITIES

1.1 Introduction

In 2006, United States residents, businesses, and institutions produced more than 251 million tons of municipal solid waste. Recycling, including composting, was successful in diverting approximately 81 million tons of materials from disposal. However, more than 50 percent of solid waste generated is being landfilled (USEPA, 2007). To reduce the amount of waste entering landfills, policymakers and governments have implemented numerous recycling and waste reduction programs. Among the programs introduced are source reduction, curbside recycling and drop-off recycling programs.

The success of a recycling program is however, largely dependent on household participation and sorting activities which are essentially behavior driven. A better understanding of recycling behavior will help us aid the design and improve the effectiveness of recycling policies. Various studies have been conducted on recycling behavior and areas examined include the motivational aspects that encourage people to recycle, the effect of socio-economic status and demographics on recycling, and the effect of knowledge and attitude on recycling (Vining and Ebreo 1990; Oskamp et al, 1991; Ebreo and Vining, 2001). These studies survey both recyclers and non-recyclers and draw conclusions based on the differences between these two groups.

Studies have also examined only recyclers, concentrating on the behavior of this particular group of people. Speirs and Tucker (2001) studied the profile of recyclers utilizing drop-off recycling sites in Glasgow and across Ayrshire in south-west Scotland. They reported recyclers' travel distances, the weights and types of recyclables and demographic characteristics. The report was generally descriptive and did not establish relationships between drop-off site utilization and the profile of recyclers. There is also a growing interest in drop-off recycling research especially by policymakers and recycling and waste management service providers. In 2004, the Ohio EPA, for example, conducted a study of participation rates and usage patterns of recyclers at drop-off sites in Ohio. That study aimed to provide the empirical evidence required by the Ohio EPA to estimate the number of users utilizing recycling sites and to assess the percentage of population in a waste management district with access to recycling facilities, to see whether it meets the regulated target percentage. We aim to add to this stream of behavioral literature by studying the profile of recyclers with a specific focus on individuals utilizing drop-off recycling sites. This is the first study that statistically analyzes the relationship between drop-off recycler characteristics and their number of visits to drop-off sites.

1.2 Literature Review

There are many reasons and factors that influence recycling. Research findings suggest that attitudes, values and the extent of environmental knowledge or concern can be used to analyze recycling behavior (Domina and Koch, 2002). Studies have investigated the effect of factors such as convenience, motivations and general attitudes towards the environment, specific recycling attitudes, knowledge and social pressure on recycling involvement.

Convenience is classified as an external facilitator that assists consumer recycling (Hornik et al, 1995). As recycling demands a significant amount of resources such as time, space, money and effort, making recycling convenient should increase household participation. In examining the differences between recyclers and non-recyclers, Vining and Ebero (1990) concluded non-recyclers were deterred by the inconvenience and the costs associated with recycling. Similarly, Domina and Koch (2002) in their study of textile recycling behavior reported that convenience is an important determinant distinguishing recyclers and non-recyclers. Saphores et al (2006) analyzed households' willingness to recycle electronic waste at drop of centers and found that convenience factors such as proximity to the drop-of center would encourage recycling. Hornik et al (1995), based on a meta-analysis, concluded that frequency of recyclables collection, which is also convenience related, was a strong predictor of recycling behavior. Gonzalez-Torre et al (2003) examined selective waste collection systems that are frequently used in Europe and America and concluded that a system that requires less time effort to dispose and separate waste will result in a higher recycling rate.

Concern for the environment is perceived to be important in encouraging recycling participation but empirical studies have shown mixed results. Domina and Koch (2002) found that people who have great concern for the environment were more likely to recycle. Meneses and Palacio (2005) in their study of the distribution of recycling tasks within the household reported that household members with positive attitudes towards ecology and who are motivated to protect the environment tend to bear a greater burden of the recycling role in the household. However, Vining and Ebero (1990) found that concern for the environment was indiscriminately expressed by both recyclers and non-recyclers. Similarly, Oskamp et al (1991) reported that general environmental attitude such as pre-ecological attitude and belief in the seriousness of environmental problems did not differ between recyclers and non recyclers.

Knowledge about the availability of recycling programs and facilities is imperative for households to effectively participate in recycling. Studies have found that knowledge about recycling programs is a strong predictor of recycling involvement (Gamba and Oskamp, 1994; Hornik et al, 1995). Vining and Ebero (1990) found that recyclers are more aware of the publicity associated with recycling and more knowledgeable about the recycling facilities in the local area. Other studies have also tried to establish the importance of knowledge about the environment in encouraging recycling behavior. Oskamp et al (1991) reported that simple conservation knowledge predicts recycling participation. Studies have also investigated the effect social influence has on recycling behavior. Social influence in this context is defined as an individual's concern about the perception of others, such as family and neighbors if they do not recycle (Vining and Ebreo, 1991). Oskamp et al (1991) and Do Valle et al (2005) reported that social influence is among the important factors that encourage people to recycle but Vining and Ebreo (1990) disagreed.

Apart from behavioral aspects, numerous studies have also looked at the relationship between demographic and socioeconomic variables and recycling involvement. The most commonly examined variables are gender, age, education and income (Saphores et al, 2006). Meneses and Palacio (2005) argued that women bore a greater burden of recycling more often than men in the distribution of recycling tasks within a household. It has been argued that women are usually associated with recycling tasks because they traditionally have more authority as far as domestic tasks are concerned (Arcury, Scollay, and Johnson, 1987). Saphores et al (2006) found that women are more willing to recycle electronic waste at drop-off centers. However, other studies found no link between gender and recycling (Gamba and Oskamp, 1994; Werner and Makela, 1998).

Other than gender, many studies have examined the relationship between age and recycling involvement. Some studies found age to be a significant factor influencing recycling involvement (Vining and Ebreo, 1990; Gamba and Oskamp, 1994; Margai, 1997; Scott, 1999; Saphores et al, 2006), but others did not (Werner and Makela, 1998; Meneses and Palacio, 2005). Contrary to popular expectation that younger people are likely to be more involved in recycling, researches have concluded that middle aged and older people are more likely to recycle (Vining and Ebreo, 1990; Meneses and Palacio, 2005; Saphores et al, 2006).

The relationship between education and recycling is ambiguous. Saphores et al (2006) found that higher education increases the willingness to recycle but several other studies reported that education has no significant effect in influencing recycling behavior (Vining and Ebreo, 1990; Oskamp et al, 1991;

Gamba and Oskamp; 1994; Meneses and Palacio, 2005). Some studies have also found a positive relationship between income level and recycling involvement (Vining and Ebreo, 1990; Oskamp et al, 1991; Gamba and Oskamp, 1994) but a study by Scott (1999) found no relationship.

1.3 Research Objectives and Hypotheses

The main objective of this study is to analyze the influence of various factors such as socioeconomic, demographic and behavioral characteristics on drop-off site visits. The behavioral aspects examined are environmental affiliation, recycling activities, and perception and attitudes towards recycling and the environment. This study also analyzes the effect of drop-off site distance from home on site visits.

We propose and test the following hypotheses:

H1: Distance to recycling sites from home reduces the number of visits.

H2: Number of different types of recyclables brought to a site increases the number of site visits.

H3: Time taken to sort recyclables increases the number of site visits.

H4: Access to curbside recycling reduces the number of site visits.

H5: Demographic factors such as age, gender, marital status, education and employment status influences the number of site visits.

H6: Affiliation with an environmental organization increases the number of site visits.

1.4 Methods

Since we seek to analyze the effects of recycler characteristics on the number of drop-off site visits, we conducted a survey of drop-off site visitors. This section describes the survey design and data collection process. This section also reports the descriptive statistics of the variables of interest. We also conducted factor analysis to reduce the number of our attitudinal variables into a few interpretable factors that were later operationalized as explanatory variables in our statistical model of drop-off site visits.

1.4.1 Questionnaire Design and Data Collection

The data for this study was collected through in-person interviews conducted at eight drop-off recycling sites around the Lansing area in Michigan. The survey (see Appendix 1) included questions on the frequency of visits to drop-off sites in the past three months and one year. Respondents' home address was elicited to allow calculation of respondents' travel distances to the recycling site. The survey also contained questions soliciting demographic information of the respondent such as gender, education, employment status income and marital status. There were questions on the respondents' recycling activities such whether they have a curbside recycling service at their residence, the types of recyclables they brought on-site, and the time they take to sort their recyclables. A question on whether the respondents are affiliated with any environmental organization was also included. The survey also included a set of questions assessing the respondent's experience and attitude towards recycling. In answering these questions, respondents were read statements and asked to indicate the extent to which they agree or disagree with the statements on a five-point Likert-scale ranging from strongly agree to strongly disagree.

The questionnaire was pre-tested and further improved before conducting the actual survey. The questionnaire pretest was conducted by interviewing several recyclers at one of the drop-off sites. The pretest resulted in some wording refinements and the changes in the arrangement of questions in the instrument. The finalized survey was conducted for four weeks, from the last week of October 2006 to the last week of November 2006. Interviews were conducted at each site four times on a three hour interval each time throughout the four week period. The survey dates chosen for all the sites were randomly selected to avoid any potential bias. During the survey, recyclers visiting the sites were approached for interviews. At the end of the survey, we approached 527 recyclers and managed to complete 356 interviews for a 68% response rate.

1.4.2 Variables Description

Table 1.1 lists and defines the demographic and other related variables that were utilized in our analysis and its definitions. Most of the variables do not require further elaboration except for a few. The variables *THREEMTHS* and *ONEYEAR* are the number of visits to the drop-off site where the respondent was interviewed in the past three months and one year. The variable *DISTANCE* represents the roundtrip distance from the respondent's home to the recycling site where the respondent was interviewed. The roundtrip distance was computed using MapQuest (www.mapquest.com). The variable *CURBSIDE* is a dummy variable indicating if the respondents have access to curbside recycling pickup at their home.

Table 1.1. Definition of variables

Variable	Definition
THREEMTHS	Total frequency of site visits in the last 3 months
ONEYEAR	Total frequency of site visits in the last 1 year
DISTANCE	Total round-trip distance from home to site
NUMREC	Number of different types of recyclables brought on site
SORTIME	Time taken (in minutes) to sort recyclables at home
CURBSIDE	Access to curbside recycling (yes=1, no=0)
CDEGREE	Educated with a bachelor's degree or higher (yes=1, no=0)
INCOME	Annual household income ($1,000's)
HSIZE	Household size
AGE	Age
MALE	Male (yes=1, no=0)
MARRIED	Married (yes=1, no=0)
FULLEMP	Employed full-time (yes=1, no=0)
ENVAFF	Affiliated with an environmental organization (yes=1, no=0)

The summary statistics of the variables (Table 1.2) indicate that the average visits of respondents to a drop-off site in the past three months and one year are approximately 4 and 15 times respectively. The average roundtrip distance traveled by the respondents to a drop-off site is around 19 miles. The respondents recycle on average 6 different materials each time they visit a drop-off recycling site, and they spend approximately 16 minutes sorting out the recyclables that they bring. Twenty five percent of the respondents reported that they have curbside recycling service at their residence. The majority of the respondents (72%) had at least four years of college education. Sixty four percent of our respondents are fully employed and the mean household income is $77,935. Our sample was comprised of 56% male respondents indicating a balanced recycling participation between genders. Seventy percent of the respondents were married, and the average household size was 2.5 people per household. Only 26% of the respondents indicate that they are affiliated with one or more environmental organizations.

Table 1.2. Summary statistics of variables

Variable	Obs.	Mean	S.D
THREEMTHS	348	4.330	3.455
ONEYEAR	348	14.652	13.804
DISTANCE	333	19.712	10.287
NUMREC	348	6.322	3.474
SORTIME	344	16.166	27.337
CURBSIDE	345	0.252	0.435
CDEGREE	348	0.718	0.450
INCOME	348	77,935	52.791
HSIZE	346	2.520	1.265
AGE	345	48.542	15.181
MALE	347	0.556	0.498
MARRIED	348	0.704	0.457
FULLEMP	348	0.641	0.480
ENVAFF	346	0.263	0.441

Table 1.3 describes the statements that are used in our survey to elicit the respondents experience, knowledge and attitude towards recycling along with the

respective distribution of Likert scale responses and descriptive statistics. The scale is defined as (1) strongly agree, (2) agree, (3) neither agree nor disagree, (4) disagree and (5) strongly disagree. Based on the mean score we can see that drop-off recyclers disagree that recycling is a difficult task (M=4.174, SD=0.825). They also disagree to both the statements of not having enough sorting time (M=4.285, SD=0.711) and storage space (M=3.797, SD=1.038) indicating that time and storage space do not deter their recycling activities. The recyclers also disagree that recyclables stored may attract pests (M=4.026, SD=0.825). Most of the recyclers agree that they are familiar with the recycling facilities (M=1.947, SD=0.847) and the materials accepted for recycling in their area's facility (M=1.724, SD=0.595).

The recyclers also agree that their family expects them to recycle (M=2.312, M=1.012). However, the recyclers are quite indifferent on the statements on whether their neighbors (M=3.303, SD=0.848) and friends (M=2.912, SD=1.012) expect them to recycle. Nevertheless, most of the recyclers feel good about themselves when they recycle (M=1.559, SD=0.579). The mean scores also show that the recyclers strongly feel that recycling is generally beneficial to the environment. The recyclers strongly agree that recycling is major way to reduce pollution (M=1.617, SD=0.653), to reduce landfill use (M=1.549, SD=0.591), to conserve natural resources (1.563, SD=0.628) and to improve environmental quality (M=1.575, SD=0.598). Additionally, these general perceptions on the benefits of recycling are strengthened by what the recyclers believe on the contributions of their activities. The recyclers strongly believe that their recycling activities will actually contribute to reducing pollution (M=1.635, SD=0.680), reducing landfill use (M=1.553, SD=0.585), conserving natural resources (M=1.571, SD=0.636) and improving environmental quality (M=1.576, SD=0.622).

Table 1.3. Definition, distribution and descriptive statistics of Likert -scale variables

		Percentage Distribution of Response					Descriptive Statistics	
Variable	**Survey Statement**	**Strongly Agree**	**Agree**	**Neither Agree Nor Disagree**	**Disagree**	**Strongly Disagree**	**Mean**	**S.D**
DIFFIC	For me, household recycling is a difficult task.	2.1%	2.9%	5.6%	54.4%	35.0%	4.174	0.825
TIME	I do not have enough time to sort the materials for recycling.	0.6%	3.5%	0.9%	56.8%	38.2%	4.285	0.711
SPACE	I do not have enough space to store the materials for recycling.	2.6%	14.7%	5.9%	53.8%	22.9%	3.797	1.038
PEST	The recyclables that I store attract pests.		10.0%	2.6%	62.1%	25.3%	4.026	0.825
FACILI	I am familiar with the recycling facilities in my area.	28.8%	57.1%	5.0%	8.8%	0.3%	1.947	0.847
MATERI	I am familiar with the materials accepted for recycling in the recycling facilities in my area.	33.2%	63.2%	1.5%	2.1%		1.724	0.595
NEIGHB	My neighbors expect me to recycle household materials.	2.9%	7.4%	55.3%	25.3%	9.1%	3.303	0.848
FRIEND	My friends expect me to recycle household materials.	9.1%	23.5%	39.4%	22.9%	5.0%	2.912	1.012

Table 1.3 (cont'd)

FAMILY	My family expects me to recycle household materials.	21.2%	46.2%	16.5%	12.6%	3.5%	2.312	1.052
GOOD	I feel good about myself when I recycle.	48.5%	47.1%	4.4%			1.559	0.579
REDPOL	Recycling is a major way to reduce pollution.	45.7%	48.7%	4.1%	1.2%	0.3%	1.617	0.653
REDLAND	Recycling is a major way to reduce wasteful use of landfills.	48.4%	49.9%	0.6%	0.9%	0.3%	1.549	0.591
NATRES	Recycling is a major way to conserve natural resources.	49.0%	47.5%	2.1%	1.2%	0.3%	1.563	0.628
ENVQ	Recycling will improve environmental quality.	46.3%	51.3%	1.2%	0.9%	0.3%	1.575	0.598
BREDPOL	I believe that my recycling activities will help reduce pollution.	44.7%	49.7%	3.5%	1.5%	0.6%	1.635	0.680
BREDLAND	I believe that my recycling activities will help reduce wasteful use of landfills.	47.9%	50.0%	1.2%	0.6%	0.3%	1.553	0.585
BNATRES	I believe that my recycling activities will help conserve natural resources.	48.5%	47.9%	1.8%	1.5%	0.3%	1.571	0.636
BENVQ	I believe that my recycling activities will help improve environmental quality.	46.8%	50.9%	0.9%	0.9%	0.6%	1.576	0.622

1.4.3 Factor Analysis

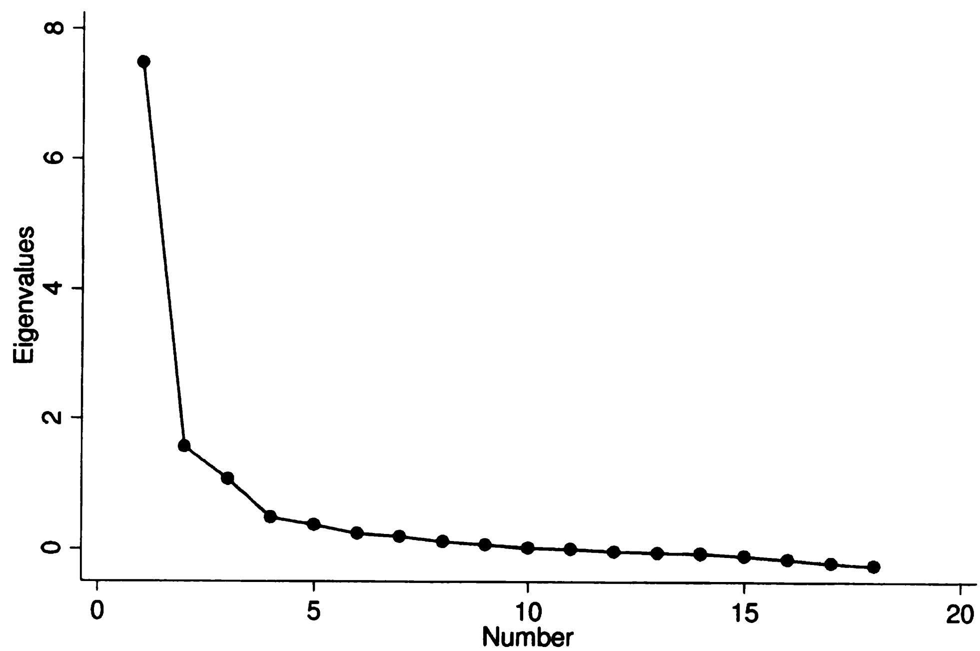
We use factor analysis with principal component analysis to group the Likert-scale variables into a small number of interpretable factors. Factor analysis will group the variables that are measuring the same construct in the same factor. This method is commonly used in social science research to reduce data into a smaller set of factors that can be used to linearly reconstruct the original variables (STATA 2003). We use the Kaiser eigenvalue criterion and the scree test to decide on how many factors to retain before proceeding with further analysis. According the eigenvalue criterion, factors with eigenvalues greater than one are retained and factors with eigenvalues less than one are considered insignificant and therefore excluded. Table 1.4 reports the initial factor extraction with the eigenvalues and percentage of variances for each successive factor. Using the eigenvalue criterion method, four factors are retained for further analysis.

Table 1.4. Total variance explained

	Initial Eigenvalues		
Factor	**Total**	**% of Variance**	**Cumulative %**
1	7.6666	42.59%	42.59%
2	2.0989	11.66%	54.25%
3	1.6771	9.32%	63.57%
4	1.1681	6.49%	70.06%

The scree test on the other hand, is a graphical method of determining the number of appropriate factors to retain. A scree test involves plotting the eigenvalue magnitudes on the vertical axis against the ordinal eigenvalue numbers on the horizontal axis and noting the point at which the plot becomes horizontal. The number of factors corresponding to the horizontal point indicates the appropriate number to retain. In Figure 1.1, the point where the line becomes horizontal starts at factor 4. Thus, the scree test indicates that we should also retain four factors, similar to the result of the eigenvalue criterion method.

Figure 1.1. Scree plot of eigenvalues and factors



We also conducted the Kaiser-Mayer Olkin's measure of sampling adequacy (KMO) test and Bartlett's test of sphericity to assess the suitability of the survey data for factor analysis (Hair et al., 1998). The results are reported in Table 1.5. The KMO is a statistical test that indicates the proportion of variance in the variables which is common variance, while the Bartlett's test is a statistical test for the presence of correlations among the variables. The KMO index ranges from 0 to 1, reaching 1 when each variable is perfectly predicted without error by the other variables. A small value (<0.05) of the Bartlett's test significance level indicates that the data do not produce an identity matrix and thus, are suitable for factor analysis. The results of the KMO and Bartlett's test show that the data meet the fundamental requirements for factor analysis.

Table 1.5. KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of sampling adequacy		0.841
Bartlett's test of sphericity	Approx. Chi2	5075
	Df	153
	Significance	<0.001

We use the Varimax rotation method (Kaiser, 1958) to rotate the four retained factors in our solution. Varimax is an orthogonal rotation method that maximizes the variance of the squared loadings for each factor. Varimax rotation will also ensure that the factors produced will be independent or unrelated to each other. The rotated factor matrix with its factor loadings is presented in Table 6. We consider variables with loadings greater than 0.4 as 'highly loaded' and are salient to the interpretation of a factor. Using this criterion, the variables are grouped together in the appropriate factor categories (refer to highlighted cells in Table 1.6). Each factor is described based on these variables and assigned descriptive names. We also compute the Cronbach's coefficient alpha for each factor to test the reliability of scales of the item variables. There is no standard cut-off point for the alpha coefficient, but it is generally agreed upon that the lower limit for Cronbach alpha is 0.7, although it may decrease to 0.6 (Hair et al.,

1998) or even 0.5 (Nunnally, 1978) in exploratory research. We then use the factor loadings to compute new variables called factor scores. These scores are composite measures indicating the degree to which an individual scores highly on a particular factor based on their responses to the variables included in that factor (Hair et al. 1998).

Table 1.6. Rotated factor matrix

Variable	Factor 1	Factor 2	Factor 3	Factor 4
DIFFIC	-0.109	0.811	-0.138	-0.115
TIME	-0.205	0.842	-0.002	-0.036
SPACE	-0.145	0.679	-0.118	-0.015
PEST	-0.231	0.410	0.104	-0.286
FACILI	0.168	-0.003	0.027	0.853
MATERI	0.224	-0.198	0.129	0.747
NEIGHB	0.042	-0.005	0.820	0.086
FRIEND	0.126	-0.092	0.799	0.020
FAMILY	0.112	-0.122	0.720	0.042
GOOD	0.482	-0.351	-0.041	0.190
REDPOL	0.873	-0.050	0.067	0.105
REDLAND	0.893	-0.106	0.015	0.101
NATRES	0.927	-0.112	0.007	0.089
ENVQ	0.877	-0.113	0.048	0.116
BREDPOL	0.877	-0.065	0.103	0.057
BREDLAND	0.917	-0.130	0.074	0.108
BNATRES	0.924	-0.075	0.016	0.079
BENVQ	0.895	-0.144	0.106	0.064

The variables that load highly into Factor 1 are *GOOD*, *REDPOL*, *REDLAND*, *NATRES*, *ENVQ*, *BREDLAND*, *BNATRES* and *BENVQ*. This factor is labeled as “Attitude” and can be best described as attitude and beliefs of the environmental benefits of recycling activities. A low score for this factor indicates that the respondents have positive attitudes and firm beliefs that their recycling activities will lead to environmental benefits such as reduced pollution and landfill use, conserving natural resources and improving environmental quality. The Cronbachs’s alpha for these items is 0.96. The item variables with high loadings on Factor 2 are *DIFFIC*, *TIME*, *SPACE* and *PEST*. We labeled this factor as ‘Convenience’ as it relates to recycling being a convenient activity to undertake. A high score for this factor signifies that the respondents regard recycling as something that is convenient to them as they have no issues of it being difficult, time consuming, space consuming and inhibitive to pests. The Cronbach’s alpha for these variable items is 0.6964.

We labeled factor 3 as ‘Social Pressure’ and the variables that load highly on factor 3 concern the social pressure on the recycler. The variables in this factor are *NEIGHB*, *FRIEND* and *FAMILY*. A low score for this factor indicates that the respondents feel that neighbors, friends and family expectations are important elements in encouraging them to recycle. The Cronbach’s alpha for factor 3 is 0.7015. The variables that load highly on Factor 4 are *FACILI* and *MATERI*. We labeled this factor as ‘Familiar’ as it relates to the familiarity of recycling facilities. A low score for this factor demonstrates that respondents are highly familiar with the recycling facilities and the materials accepted in the recycling facilities in their area. The Cronbachs’s alpha for factor 4 is 0.579.

Table 1.7. Factors, item variables and Cronbach's alpha

Factor	Item Variables	Cronbach's α
(1) Attitude	*GOOD, REDPOL, REDLAND, NATRES, ENVQ, BREDLAND, BNATRES, BENVQ*	0.960
(2) Convenience	*DIFFIC, TIME, SPACE, PEST*	0.696
(3) Social Pressure	*NEIGHB, FRIEND, FAMILY*	0.702
(4) Familiarity	*FACILI, MATERI*	0.579

Table 1.7 outlines the factors, their respective variables as extracted by the factor analysis, and their Cronbach's alpha coefficient. The factors condense the experience, knowledge and attitude towards recycling of our survey respondents into four new interpretable variables; namely Attitude, Convenience, Social Pressure and Familiarity. We use the factor score of these four new variables to ascertain their relationship to the usage of drop-off sites.

1.5 Analysis and Results

A key element of this paper is to analyze the variables that influence visits to drop-off recycling sites. This section develops a visitation model to relate the effects of demographics, recycling activities, environmental affiliation and the variables derived from the factor analysis to the number of trips taken to a drop-off site. The visitation model is developed using the Poisson regression method. Poisson regression is utilized because the data for our dependent variable, the trips an individual takes to a recycling site y_i, are classified as a count variable where y_i can only take discrete values ($y_i = 1,2,3,...$). More specifically, we will use the endogenous stratified and truncated Poisson regression since we use do not observe zero trips for any of the sample members as our sample is obtained via the on-site sampling method. Following Haab and McConnell (2002) the Poisson probability with on-site endogeneity and truncation is expressed as follows:

$$\Pr(y_i|y_i > 0) = \frac{e^{-\lambda_i}\lambda_i^{y_i-1}}{y_i - 1!} \qquad (1)$$

where λ_i is both the mean and the variance of the distribution. Since it is necessary for $\lambda_i > 0$, it is commonly specified as an exponential function:

$$\lambda_i = \exp(x_i\beta) \qquad (2)$$

where x_i is a vector of explanatory variables. Equation 1 can be simplified by re-writing it as:

$$\Pr(y_i|y_i > 0) = \frac{e^{-\lambda_i}\lambda_i^{y_i'}}{y_i'!} \qquad (3)$$

where $y_i' = y_i - 1$. Using equation 3, we obtain the log-likelihood of a Poisson function

$$\ln(\beta|X,y) = \sum_{i=1}^{T}\left[-e^{X_i\beta} + X_i\beta y_i - \ln(y_i'!)\right] \qquad (4)$$

and thus, the on-site endogenous and truncated Possion can be estimated by simply running a standard Poisson regression of $y_i - 1$ on all X_i's.

Table 1.8 presents the results of the Poisson regression models predicting the number of trips taken to a recycling drop-off site in the last one year[1]. There are two models in this analysis; Model 1 is the basic model that uses distance, number of recyclables, sorting time, access to curbside recycling and

[1] We also ran the regressions using the trips in the past three months as the dependent variable and found similar results but with less explanatory power.

demographic variables as dependent variables. Model 2 is the extended model that also includes all four Likert-scale variables derived from the previous factor analysis along with all of the basic variables in Model 1. The results show that both models 1 and 2 are statistically significant with the likelihood ratio statistics of 445.64 and 546.17 respectively.

The coefficients in Model 1 are all statistically significant at 5% and 1% level except for *CURBSIDE, MALE* and *ENVAFF*. In this model, access to curbside recycling services, gender and environmental affiliation play no statistically significant role in increasing the expected number of site visits. The coefficients on *NUMREC*, *INCOME*, *HSIZE*, *AGE* and *MARRIED* in Model 1 are positive and the coefficients on *DISTANCE, SORTIME, CDEGREE* and *FULLEMP* are found to be negative. The significance level of the coefficients in Model 2 after adding the four attitudinal variables did not change much except for *CURBSIDE* and *MARRIED*. The sign of the coefficient on access to curbside recycling remains negative but the variable is now statistically significant at the 5% level. The variable *MARRIED* is no longer significant. The coefficients on *NUMREC*, *INCOME*, *HSIZE* and *AGE* in the extended model remain positive. The coefficients on *DISTANCE*, *SORTIME*, *CDEGREE* and *FULLEMP* remain negative and statistically significant. Three of the four attitudinal variables; *CONVENIENCE*, *FAMILIAR* and *SOCIAL* are significant at the 1% level. *FAMILIAR* and *SOCIAL* have negative signs and *CONVENIENCE* has a positive sign.

Table 1.8. Poisson regression

(Dependent variable = *ONEYEAR i.e. number of visits in the past year*)				
	Model 1		**Model 2**	
Variable	**Coeff.**	**Std. Error**	**Coeff.**	**Std. Error**
DISTANCE	-0.010	0.001**	-0.011	0.002**
NUMREC	0.050	0.005**	0.050	0.005**
SORTIME	-0.005	0.001**	-0.004	0.001**
CURBSIDE	-0.061	0.040	-0.082	0.041**
CDEGREE	-0.129	0.035**	-0.105	0.036**
INCOME	0.001	0.0003*	0.001	0.0003**
HSIZE	0.067	0.014**	0.079	0.014**
AGE	0.007	0.001**	0.005	0.001**
MALE	0.026	0.032	0.045	0.033
MARRIED	0.118	0.041**	0.058	0.043
FULLEMP	-0.349	0.034**	-0.378	0.035**
ENVAFF	0.059	0.036	-0.018	0.039
CONVENIENCE			0.039	0.016**
FAMILIAR			-0.148	0.017**
SOCIAL			-0.080	0.017**
ATTITUDE			0.019	0.017
CONSTANT	2.128	0.082**	2.238	0.083**
Observations	329		322	
Log-likelihood	-2315.49		-2172.55	
$-2\ln(L_R/L_U)$	445.64		528.47	
Pseudo R^2	0.09		0.11	

**$\alpha < 0.01$, *$\alpha < 0.05$

The coefficients on *DISTANCE* in both models imply that the expected number of visits reduces by 1% as roundtrip distance from home to site increases by a mile. This result strengthens the findings by Saphores et al (2006) that improved proximity to recycling sites would encourage recycling behavior. The coefficients on *NUMREC* in both models indicate that the number of site visits is expected to increase when a recycler recycles a wider variety of recyclables. The time taken to sort the recyclables at home was found to reduce the expected number of site visits. The *SORTTIME* coefficient in Model 2 indicates that a 10 minute increase in sorting time reduces the expected number of site visits by 4%. It is also expected that people with curbside recycling service at their residents too have less frequent visits to drop-off sites as many of their recyclables are collected at the curb. The coefficient for CURBSIDE in Model 2 suggests that the availability of curbside recycling reduces the expected number of site visits by 8.2%.

The results show that people with a bachelor degree or higher are expected to have fewer site visits when compared to less educated people. The *CDEGREE* coefficient in Model 2 indicates that having a bachelor degree reduces the expected number of site visits by approximately 10%. One possible explanation is educated people tend to have busier jobs and were likely to allocate less time on recycling activities. The negative coefficients on *FULLEMP* also indicate that people who are employed full time are likely to spend less time on recycling activities when compared to people who are employed part time or unemployed. The results demonstrate that an increase in annual household income is expected to increase the expected number of site visit in both models. This result also confirms the findings by Vining and Ebreo (1990), Oskamp et al (1991), and Gamba and Oskamp (1994) that income level increases recycling involvement. The positive relationship between household size and the expected number of visits is very much anticipated as larger households tend to consume more goods. The positive relationships between age and number of site visits found in both models are also consistent with previous findings that older people have a higher tendency to recycle (Vining and Ebreo, 1990; Meneses and Palacio, 2005; Saphores et al, 2006).

The positive coefficient of the variable *CONVENIENCE* in Model 2 indicates that the number of expected site visits increases when recycling is regarded as a convenient activity. This result confirms the previous findings that convenience is an important factor that encourages recycling behavior (Vining and Ebero, 1990; Hornik et al, 1995; Domina and Koch, 2002; Gonzalez-Torre et al, 2003; Saphores et al, 2006). The coefficient for *FAMILIAR* suggests that people who are more familiar with locations and materials accepted at the drop-off center in his or her vicinity are expected to make more visits to the centers than the less familiar people. The coefficient for *SOCIAL* implies that peers and family pressure has a positive effect on drop-off site visits. This result conforms to the findings of previous studies that indicate social pressure is an important factor motivating recycling behavior (Oskamp et al, 1991; Do Valle et al, 2005).

1.6 Conclusions

The success of a drop-off recycling program, similar to other recycling programs, is largely dependent on the participation of the public. This study helps us understand the profile of people who utilize drop-off recycling sites as well as some of the underlying factors that influence their frequency of use. The results from this study demonstrate that drop-off site utilization is influenced by demographics factors such as age, education, income and household size. These results corroborate the findings of previous studies that include demographic effects in analyzing recycling behavior.

This study also found that location plays a crucial role in influencing the usage pattern of drop-off sites. Recyclers are likely to use a drop-off site more frequently if the travel distance from home to site is shorter. Thus, the decision to establish a drop-off recycling program should factor in location to encourage its use. There are also perception and attitudinal factors that affect drop-off site visits. Recyclers tend to use the drop-off sites more when they feel that recycling is a convenient activity. This study also found that familiarity of the recycling sites and recyclables accepted is associated with increased usage of drop-off facilities. This suggests that promotion of drop-off recycling facilities and the materials accepted could be used to encourage drop-off recycling activities.

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ESSAY 2. ESTIMATING THE DEMAND FOR DROP-OFF RECYCLING SITES: A RANDOM UTILITY TRAVEL COST APPROACH

2.1 Introduction

The four primary methods to collect recyclables in the United States are curbside programs, drop-off centers, buy-back centers, and deposit or refund programs (USEPA, 2007). Drop-off recycling is a recycling program where designated sites are established to collect a range of recyclables and usually the recyclers themselves are required to deposit the sorted recyclables in specially marked containers. Drop-off recycling is also one of the most widely adopted recycling programs by local governments in this country. As of 1998, there were 12,000 recyclable drop-off sites and 9,000 curbside programs established in the United States (USEPA, 2000).

Drop-off recycling centers are less costly to operate compared to curbside programs, and they are also faster to implement than take-back programs or other similar programs involving manufacturers (Saphores et al, 2006). Drop-off program operators are able to save on labor and transportation costs because these costs are transferred to the recyclers. Drop-off operations typically do not impose any charges to recyclers utilizing drop-off sites. Drop-off recycling is also considered to be the most financially viable recycling option in areas with low population density such as in rural areas or the countryside (Tiller, Jakus and Park, 1997).

There is a need to understand community participation and effectiveness of drop-off recycling sites to assist policymakers in making better recycling and waste management decisions. In 2004, Ohio EPA conducted a study to learn more about waste diversion amounts, recycling participation rates and usage patterns at drop-off recycling sites in Ohio. This information is required by the authority to more accurately grant population access credits to solid waste management districts in Ohio for the drop-off recycling programs in their jurisdiction[2].

Despite its wide implementation, relatively little literature addresses the demand for drop-off recycling. Curbside recycling as a waste management policy tool is the more popular research area in the field of recycling and waste management. Fullerton and Kinnaman (1996), Hong and Adams (1999), Van Houtven and Morris (1999), Kinnaman and Fullerton (2000), Jenkins et al (2003) analyze the effect of curbside recycling, together with other policy tools such as variable garbage pricing, on the amount of waste generation and recycling. Other curbside recycling research investigates the values consumers place on curbside recycling by computing their willingness to pay for the service (Lake et al, 1996; Aadland and Caplan, 1999; Aadland and Caplan, 2003; Blaine et al, 2005).

One of the few exceptions of recycling research that is related to drop-off recycling is the stated preference study of a drop-off program conducted by Tiller, Jakus and Park in 1997. Their study analyzed the economic feasibility of establishing a drop-off recycling program in a rural and a suburban area of Tennessee by utilizing the contingent valuation method to calculate household

[2] Access credit is the number of people with access to recycling facilities in a solid waste management district in Ohio. The access credit is divided over the population of a district to determine if the district complies with the minimum required percentage of the population with access to recycling facilities.

willingness to pay (WTP) for the program. The estimated WTP for the three different types of households controlled for respondents' income, education level, age and attitudes toward the importance of recycling. They found that suburban recyclers, which consist of households with curbside recycling services, are willing to pay the most for drop-off recycling, with a mean WTP point estimate of $11.74 per month. Rural recyclers have a mean WTP of $7.07, and rural non-recyclers have the lowest mean household WTP of $4.05.

Chang and Wei (1999) examine the strategic planning aspects of drop-off recycling centers in Kaohsiung, Taiwan. Their study analyzed the trade-off between the number and size of drop-off centers, walking distances to the drop-off centers, population covered in a service area and the driving distance of collection vehicles. The analysis was conducted by formulating a multi-objective mixed-integer linear programming model which balanced the following objectives: to maximize the population served by recycling centers, to minimize walking distance and to minimize total routing distance of collection vehicles subject to several physical constraints such as limit on drop-off centers in an area, service efficiency, capacity limitations, scheduling limitation and service area.

There are also a few other studies that have indirectly looked into drop-off recycling. Folz (1991) in a study examining the success of recycling programs reported that solid waste management experience of recycling coordinators is a very important factor in maximizing participation in drop-off programs. It was argued that experienced coordinators make better decisions in choosing the best strategic locations for drop-off centers. Folz also reported that advertising and promotion of recycling results in higher waste diversion to drop-off programs. In a descriptive study, Speirs and Tucker (2001) examined the profile of recyclers utilizing drop-off recycling sites in Glasgow and around Ayrshire in south-west Scotland. They reported on the recyclers' travel distances, the weights and types of recyclables and demographic characteristics. They also found that people whose trips were solely for the purpose of recycling tend to be a shorter distance from the sites compared to people who combine their recycling trips with other activities. In a more recent publication, Saphores et al (2006) studied willingness to recycle electronic waste at drop-off centers by conducting a mail survey of households in California. The results from their multivariate analysis indicated that familiarity and convenience were very important factors in influencing willingness to recycle. People who are familiar or accustomed with glass, metal, paper or plastic recycling are more willing to recycle electronic waste. The study also found that people who lived more than 5 miles away from the nearest drop-off recycling center were less likely to recycle.

In comparison to the broader literature on recycling, and specifically the attention paid to curbside recycling, there are relatively few studies that emphasize drop-off recycling. We address this gap by studying the demand for drop-off recycling sites in an urban area with several substitute sites using the random utility model (RUM). The main objective of this study is to examine the impact of location and different drop-off recycling site characteristics on drop-off recycling visits. We hypothesize that the travel costs incurred by recyclers to drop-off sites reduce site visits. We also hypothesize that site specific characteristics such as operating hours, number of recyclables accepted, acceptance of commingled recyclables and acceptance of yardwaste affect recycling visits. This study also uses the RUM model to predict the changes in drop-off recycling patterns given the changes in site characteristics. This study improves our understanding on attributes of drop-off sites that may influence visitation demand. The study findings can be used by local governments and recycling and waste management companies to design and establish recycling drop-off centers that will increase site visitation and collection of recyclables.

Our study utilizes the revealed preference approach which is different from the study conducted by Tiller et al (1997) that uses the stated preference approach. Unlike stated preference studies that rely on a respondent's survey answers on monetary amounts, choices, ratings or other preference indications to establish a measure of value on non-market goods or services (Brown, 2003), a revealed preference study collects information on respondents' actual behavior, such as number of visits and cost of traveling to particular sites, to establish the demand and value of these non-market goods or services. The RUM model which originates from the transportation field is widely used within the field of environmental economics to analyze the demand for recreational sites. We believe that our study is a novel application of the RUM travel-cost method to estimating the demand for local public services such as drop-off recycling sites.

2.2 Theoretical Framework

The RUM model is widely used to analyze discrete choices in the face of many substitutes. In our case, the RUM is appropriate because it is able to consider a household's selection of a drop-off recycling site, chosen from a set of many alternative drop-off sites, on an occasion in which they have chosen to visit a drop-off site. While the decision to utilize a drop-off site has many elements of a cost minimizing decision, we posit that households also have preferences (and hence derive utility) from the convenience attributes and other attributes of recycling sites. Thus, when selecting a site the household is assumed to take into account the trip cost to arrive to the site as well as the site characteristics. The trip cost would mainly be the driving cost and time cost to travel to and from the site. Site characteristics are the features of each drop-off site such as operating hours and types of recyclables accepted. Hence, each recycling site will give households different utility levels and, after factoring in the travel costs, households are assumed to visit sites that yield them the highest utility.

Specifically, to model the drop-off site selection process, we assume that households derive utility from the quality or characteristics of a particular drop-off site. Each household has a choice set of S number of sites that they could visit denoted by $j = 1,2,\ldots S$. Let x_{ij} represent trips household i takes to site j with a vector of M site characteristics $[q_{j1}, q_{j2}, \ldots q_{jM}]$. In evaluating the utility household i derives from a trip to site j, we assume that $q_k = 0$ for all $k \neq j$. The utility function for household i is defined as follows

$$U\{z_i, x_{ij}(q_{j1}, q_{j2}, \ldots q_{jM})\} \tag{1}$$

where z_i is a composite consumer good and the utility function is assumed to be increasing and strictly quasi-concave in all its arguments. Households maximize utility subject to a budget constraint (2) and time constraint (3).

$$\sum_{j=1}^{n} x_{ij} c_{ij} + z_i \le y_i \tag{2}$$

$$\sum_{j=1}^{n} x_{ij} t_{ij} + h_i + l_i \le T \tag{3}$$

where c_{ij} is the return-trip driving cost to site j, z_i is purchased at a normalized price equal to 1, y_i is the household income which is further defined in (4), t_{ij} is the time taken for each round-trip to site j, h_i is the hours spent working, l_i is the time spent for leisure and T is the total time available. Income is given by

$$y_i = y_i^0 + w_i h_i \tag{4}$$

where y_i^0 is fixed income and w_i is the wage rate. Solving the time constraint using equation (4) for h and substituting it into the budget constraint yields

$$\sum_{j=1}^{n} x_{ij} (c_{ij} + w_i t_{ij}) + z_i \le y_i \tag{5}$$

By solving the utility maximization problem, we derive the Marshallian demand function for x_{ij} and substituting the demand function in the utility function results in the indirect utility function that is expressed as follows:

$$v_{ij} = v(y_i - (c_{ij} + w_i t_{ij}), q_j) \tag{6}$$

The indirect utility function can be represented in a linear form where βs are the parameters to be estimated and e_{ij} is the random error term

$$v_{ij} = \beta(y_i - (c_{ij} + w_i t_{ij})) + \beta_q q_j + e_{ij} \tag{7}$$

The cost of visiting site j that consists of round-trip driving and time costs, $c_{ij} + w_i t_{ij}$ is essentially the travel cost which will be simplified as tc_{ij}. We also note that y_i will drop from the equation as it does not vary across sites. Thus, the indirect utility function can rewritten as follows

$$v_{ij} = \beta_{tc} tc_{ij} + \beta_q q_j + e_{ij} \tag{8}$$

On a given a choice occasion, a household decides to recycle at the site that yields the highest utility. A recycling site *k* is chosen by household *i* if:

$$\beta_{tc} tc_{ik} + \beta_q q_k + e_{ik} \geq \beta_{tc} tc_{ij} + \beta_q q_j + e_{ij} \text{ for all } j \in S \tag{9}$$

We could express the choice to visit a recycling site in a probabilistic framework, where the probability of a household visiting site *k* is:

$$\Pr(\beta_{tc} tc_{ik} + \beta_q q_k + e_{ik} \geq \beta_{tc} tc_{ij} + \beta_q q_j + e_{ij} \text{ for all } j \in S) \tag{10}$$

The choice probability of household *i* visiting site *k* could be expressed using the conditional logit form, where:

$$\Pr(ik) = \frac{\exp(\beta_{tc} tc_{ik} + \beta_q q_k)}{\sum_{j=1}^{S} \exp(\beta_{tc} tc_{ij} + \beta_q q_j)} \tag{11}$$

The model estimators can be derived by maximizing the following log-likelihood function constructed from equation 11

$$\log L_n(y, \beta) = \sum_{n=1}^{N} \log P \left(\frac{\exp(\beta_{tc} tc_{ik} + \beta_q q_k)}{\sum_{j=1}^{S} \exp(\beta_{tc} tc_{ij} + \beta_q q_j)} \right) \tag{12}$$

The equation in (12) provides the likelihood function for a random sample of drop-off recyclers. However, if our data is collected using a choice-based or an on-site sampling method, then we would need to correct for the potential endogenous stratification in the data. With on-site sample data, if we know the population proportions of recyclers visiting the *S* sites, we can to use the Weighted Exogenous Sampling Maximum Likelihood (WESML) method to derive consistent estimates of the model parameters (Manski and Lerman, 1977). The WESML estimator is obtained by weighting the population proportions by the sample proportion and incorporating these weights in the likelihood function. From equation 12, the weighted exogeneous likelihood function is presented as follows

$$\log W_n(y,\beta) = \sum_{n=1}^{N} \frac{Q_j}{H_j} \log P\left(\frac{\exp(\beta_{tc} tc_{ik} + \beta_q q_k)}{\sum_{j=1}^{S} \exp(\beta_{tc} tc_{ij} + \beta_q q_j)} \right) \tag{13}$$

where Q_j is the proportion of the population selecting site *j* and H_j is the analogous proportion for our choice based sample. To use the demand model to forecast changes, we use the WESML estimates for the parameters to predict the probability for the households across our sample.

2.3 Survey Methods

2.3.1 Questionnaire Design

The questionnaire used in this study consists of questions pertaining to the respondent's recycling activities. We include questions on the frequency of visits to drop-off sites in the past three months and one year to calculate site visits. Questions on the respondent's income and home address are also included in the questionnaire to compute the travel costs. These questions occurred at the end of the interview because we felt respondents would be more comfortable sharing this more personal information after going through a set of more general questions. On the home address question, we asked the nearest street intersection to the respondent's home whenever they were reluctant to reveal their address.

The questionnaire also consists of questions eliciting general demographic information of the respondent such as gender, education, employment status and marital status. The questionnaire was pre-tested and further improved before conducting the actual survey. The questionnaire pretest was conducted by interviewing several randomly selected recyclers at one of the drop-off sites. The pretest resulted in some wording refinements and changes to the arrangement of questions in the instrument.

2.3.2 Data Collection

We define our population to consist of recyclers utilizing eight drop-off recycling sites in and around Lansing, Michigan. We used on-site interviews to collect our survey data. This survey method is chosen over a random population survey because we expect the percentage of population that recycles at drop-off sites to be low and we would require a large sample size to obtain sufficient number of drop-off recyclers in such a sample. Furthermore, with low proportions for the target population, the costs involved in conducting a detailed survey with such large sample size are also high. Manski and Lerman (1977) suggest that choice based survey can achieve the economies of scale not available with a population survey in circumstances where the respondents are physically clustered according to the alternative they select. Similarly, Haab and McConnell

(2002) noted that on-site sample surveys are a more cost effective approach for data collection for multiple site models when the proportion of the population participating in the activity is quite low.

However, there is a problem associated with on-site sample surveys - the sampling scheme is often independent of the population proportions visiting the survey sites. The problem arises as model parameter estimates depend on the sampling proportions. If the sampling proportions differ from the population proportions, the model will suffer from inconsistent parameter estimates. In other words, sampling proportions that differ from population proportion will result in the parameter estimates capturing both the sampling plan and recycler's behaviors, rather than behavior alone. Nevertheless, the on-site sampling endogeneity problem can be addressed if the population proportions are known. Specifically, consistent parameters can be estimated using the WESML method if the population shares are known (Manski and Lerman, 1977).

There were two separate processes involved in obtaining our survey data: the first part was to measure recycling effort at each drop-off site and the second part was to conduct on-site interviews of recyclers. The measures of recycling effort at each site are used to estimate the population proportions of the eight drop-off sites to construct the WESML weights to correct for possible choice-based sampling bias. To measure recycling effort, we counted the vehicles visiting each of the drop-off sites. The counting exercise was conducted simultaneously at each site, except for Site 8 due to the site's operating hours restriction (see Appendix: Table A.1). We selected Saturday, October 21, 2006, 9am to 2pm for the car counting exercise for the seven drop-off sites to capture the busiest recycling period. The car counting for Site 8 was conducted on Monday, October 23, 9am to 2pm, as we expected the traffic at this time to be the busiest, thus equivalent to weekend traffic at other sites. Table 2.1 provides the distribution of cars according to recycling sites.

Table 2.1. Distribution of cars by sites from the effort survey

Site Name	Cars	Percentage
Site 1	146	25.44%
Site 2	202	35.19%
Site 3	113	19.69%
Site 4	29	5.05%
Site 5	50	8.71%
Site 6	26	4.53%
Site 7	3	0.52%
Site 8	5	0.87%

For the second part, on-site survey interviews were conducted for four weeks starting from the last week of October 2006 to the last week of November 2006. Each site was randomly visited 4 times, on a three-hour interval each time throughout the survey period. For each visitation time, we randomly selected the sites. A site that was not open on a particular visitation time was excluded to ensure a zero probability of selection for that time. With the exception of Site 2 and Site 8, we excluded sites that had been selected on the same visitation time in the previous weeks. For example, if Site 1 had been selected for Week 1, Sunday 3-6pm, the site was excluded in the drawing for that time period for Week 2 at the same time. We made an exception for Site 2 and Site 8 because both sites have limited operating hours and if we were to impose a duplicate time restriction on these sites, the sites would have been visited less than 4 times. A site was excluded from the draw once it had been selected 4 times (see Table A.2 in Appendix for the detailed survey schedule). At the end of the survey duration, we approached 527 recyclers. Out of the total approaches made, 356 recyclers agreed to participate in the survey giving us a response rate of approximately 68%.

The distribution of respondents according to recycling sites is given in Table 2.2. We obtained the highest number of respondents from Site 1 which represents 26.4% of the total sample. The second highest number of respondents was obtained from the Site 3 followed by the Site 2, representing 22.75% and 20.51% of the total sample. The percentage distribution of respondents for Site 5, Site 6, Site 4 and Site 8 are 12.36%, 8.43%, 5.34% and 3.09% respectively. The lowest number of respondents is from Site 7 constituting only 1.12% of the total sample.

Table 2.2. Distribution of respondents by sites from the on-site survey

Site name	Respondents	Percentage
Site 1	94	26.4%
Site 2	73	20.51%
Site 3	81	22.75%
Site 4	19	5.34%
Site 5	44	12.36%
Site 6	30	8.43%
Site 7	4	1.12%
Site 8	11	3.09%

Table 2.3 presents the demographic profile of the recyclers in our sample. We had more males (55.62%) than female respondents (44.38%) in the survey. With regards to age, the majority of the respondents are 40 years or older, and the highest age group was between 50 to 59 years old (28.16%). The lowest age group was between 30 to 39 years old which accounts to only 10.92% of the respondents. As for household composition, about 71% of the respondents are either married or living with a partner. Approximately 80% of the respondents lived in a household comprised of 2 or more people. The respondents were mostly college-educated as approximately 70% of the sample have a bachelor's degree or higher. The majority of the respondents were also employed full time (64.27%). In terms of household income, roughly 60% of the respondents reported a household income of $45,000 or more.

Table 2.3. Demographic characteristics of drop-off recyclers

Variable	Frequency	Percentage
Gender		
Male	154	44.38
Female	193	55.62
Age		
18 to 30 years old	56	16.09
30 to 39 years old	38	10.92
40 to 49 years old	86	24.71
50 to 59 years old	98	28.16
60 years old or more	70	20.11
Education		
Some high school	3	0.86
High school or GED	54	15.56
Vocational or trade school	5	1.44
Two year degree	36	10.37
Four year degree	133	38.33
Graduate school	116	33.43
Employment Status		
Employed full time	223	64.27
Employed part time	29	8.36
Unemployed	3	0.86
Retired	63	18.16
At home parent	8	2.31
Student	21	6.05
Income		
Less than $25,000	43	12.36
$25,000 to $44,999	75	21.55
$45,000 to $74,999	78	22.41
$75,000 to $99,999	77	22.13
$100,000 or more	75	21.55
Marital Status		
Single	69	19.94
Married/Living with partner	245	70.81
Divorced/Widowed/Separated	32	9.25
Household Size		
1	65	18.79
2	149	43.06
3	53	15.32
4	57	16.47
5	13	3.76
more than 5	9	2.60

2.4 Model Estimation and Results

We estimated our basic model using the WESML estimation method and the model was specified as follows:

$$\begin{aligned} v_{ij} = {} & \beta_1 TRAVELCOST_{ij} + \beta_2 HOURS_{ij} + \beta_3 NUMREC_{ij} \\ & + \beta_4 COMMING_{ij} + \beta_5 YARDWASTE_{ij} + e_{ij} \end{aligned} \tag{14}$$

where v_{ij} is the indirect utility individual i gets from visiting site j, and each j has the same independent, Type 1 extreme value distribution,

$$F_e(e_{ij}) = \exp(-\exp(-e_{ij})) \tag{15}$$

which, under maximization, yields the conditional logit model for the choice probabilities as in (11). We also examine an extension of the basic model by incorporating interactions between demographic variables and the site attributes. The extended model is specified as follows:

$$\begin{aligned} v_{ij} = {} & \beta_1 TRAVELCOST_{ij} + \beta_2 HOURS_{ij} + \beta_3 NUMREC_{ij} \\ & + \beta_4 COMMING_{ij} + \beta_5 YARDWASTE_{ij} + \beta_6 EHOURS_{ij} \\ & + \beta_7 ENUMREC_{ij} + \beta_8 ECOMMING_{ij} + \beta_9 EYARDWASTE_{ij} \\ & + \beta_{10} HHOURS_{ij} + \beta_{11} HNUMREC_{ij} + \beta_{12} HCOMMING_{ij} \\ & + \beta_{13} HYARDWASTE_{ij} + e_{ij} \end{aligned} \tag{16}$$

Table 2.4 provides a list of variables and their definition. For each site and for each respondent, the travel cost variable was calculated by adding up the roundtrip driving cost and the time cost to travel from the recycler's home a drop-off site. The distance from home to the recycling site was obtained with Mapquest using the shortest distance option. The driving cost was assessed at 35 cents per mile (AAA, 2006). Driving cost consists of per mile vehicle operating cost plus depreciation per mile. Time cost was the opportunity cost incurred by the recycler during the drop-off recycling activity calculated using the recycler's income. The trip time is computed assuming that a recycler travels at 35 miles per hour on average. The recreation literature has generally accepted 1/3 of an individual's wage as a lower bound and an individual's full wage as an upper bound for the hourly value of time spent driving (Parsons, 2003). We use the recycler's full wage in our time cost calculation and the wage is computed by dividing annual income by 2080 hours of work time (52 weeks at 40 hours per week).

Table 2.4. Definition of variables

Variable	Definition
TRAVELCOST	Roundtrip travel and time cost from home to site j
HOURS	Total operating hours per week
NUMREC	Number of recyclables accepted
COMMING	Number of types of commingled recyclables accepted
YARDWASTE	1 if site accepts yard waste (0 otherwise)
EHOURS	Interaction between full employment dummy (1= fully employed, 0=otherwise) and *HOURS*
ENUMREC	Interaction between full employment dummy and *NUMREC*
ECOMMING	Interaction between full employment dummy and *COMMING*
EYARDWASTE	Interaction between full employment dummy and *YARDWASTE*
HHOURS	Interaction between household size (= the number of household members) and *HOURS*
HNUMREC	Interaction between household size and *NUMREC*
HCOMMING	Interaction between household size and *COMING*
HYARDWASTE	Interaction between household size and *YARDWASTE*

The site characteristics data used in our model were obtained from the information given at the site and through our own observations. The operating hours for the recycling sites varied from as low as only 15 hours per week to 24 hours a day. We expect operating hours per week to increase site visitation because it increases flexibility and convenience for recyclers. The number of recyclables accepted also varies from site to site. There are sites accepting as few as only 5 types of recyclables to a site that accepts 17 different types of recyclables. We expect sites accepting a wider range of recyclables to receive higher visitation rates when compared to sites accepting a limited range of recyclables. There are sites that accept commingled plastic or papers and recyclers visiting these sites are not required to separate the different types of recyclable plastics or papers. This attribute is expected to increase site visits as it makes recycling easier and more convenient. We also included a dummy variable to represent sites that accept yardwaste. The sites that accept yardwaste are Site 1, Site 2, Site 3 and Site 8 and they charge fees ranging from $5 to $10 per cubic yard of yardwaste recycled. However, as Site 2 only accepts yardwaste from its township residents, the yardwaste dummy variable for Site 2 will only take a value of 1 if the respondent lives in the township where Site 2 is located.

EHOURS, *ENUMREC*, *ECOMMING*, *EYARDWASTE* are the interactions between the dummy variable for full employment and the attribute variables; operating hours, number of recyclables accepted, acceptance of commingled recyclables and acceptance of yardwaste. These variables are included to ascertain the degree of influence of the site attributes on drop-off site visits for persons with a full-time employment. We also interact household size (the number of people in the household) with the same four attribute variables to form HHOURS, *HNUMREC*, *HCOMMING*, *HYARDWASTE* to determine if households with different sizes place a different weight on the site attributes.

The estimation results are presented in Table 2.5. Model 1 is the basic model, and Model 2 is the extended model that includes interaction variables between demographics and site attributes. All the parameters in Models 1 are statistically significant, and all the parameters in Model 2 are statistically significant except for *NUMREC*. The travel cost variable is negative and highly significant as expected in both the models. In other words, the parameter indicates that by holding all other variables constant, it is expected that the probability of visiting a recycling site will decrease as the cost of traveling to the site increases. The parameter estimates for the travel cost variable in both models are also very similar. The estimates for *YARDWASTE* indicate that yardwaste acceptance has a large impact on increasing the probability of site visits. The parameter estimates for *HOURS* indicate that increasing site operating hours per week will increase site visits. However, this interpretation is only applicable to non 24 hour sites.

Table 2.5. Random utility model results

(Dependent variable = *Number of visits in the past year*)	Model 1		Model 2	
	Estimate	Std. Error	Estimate	Std. Error
TRAVELCOST	-0.144	0.005**	-0.145	0.005**
HOURS	0.010	0.001**	0.002	0.001*
NUMREC	0.196	0.011**	0.001	0.023
COMING	0.501	0.035**	0.766	0.087**
YARDWASTE	2.260	0.082**	1.041	0.171**
EHOURS			0.010	0.001**
ENUMREC			0.039	0.021*
ECOMMING			0.208	0.076**
EYARDWASTE			0.767	0.152**
HHOURS			0.001	0.0005**
HNUMREC			0.078	0.011**
HCOMMING			-0.152	0.028**
HYARDWASTE			0.383	0.075**
Observations	343		342	
Adj-R2	0.472		0.489	
Log-likelihood	-6607		-6306	

**α < 0.01, *α < 0.10

The results in Model 1 also imply that increasing the number of recyclables accepted at a drop-off site will increase the probability of site visits. The parameter estimates for *COMMING* in Model 1 indicate that allowing for an additional type of commingled recyclables will increase the probability recyclers visit that drop-off site. *NUMREC* is no longer significant in Model 2 although its interaction with the fully employed and household size variables are both significant. The positive parameter estimates for *EHOURS*, *ENUMREC*, *ECOMMING* and *EYARDWASTE* in Model 2 suggests that site attributes such as operating hours, the number of recyclables, acceptance of commingled and acceptance of yardwaste have more impact in increasing site visits for recyclers that are working full-time. This result is intuitive as one would expect a fully employed person to be more occupied and might place a higher value on convenience-related site attributes when compared to recyclers who are not employed. The positive estimates for *HHOURS*, *HNUMREC* and *HYARDWASTE* indicate that site operating hours, the number of recyclables and acceptance of yardwaste have more impact in increasing site visits for larger households. Perhaps not intuitive, the negative parameter estimate for *HCOMMING* suggests that the acceptance of commingled recyclables would reduce recycling visits of larger households.

In interpreting the results for the site attribute variables, it is important to note that with only eight sites in the model, there are limitations on the independent variation in the site attributes. Indeed, with the exception of travel costs, we found some evidence of multicolinearity between the site attributes. Further, with only eight sites in our model, we can include a maximum of eight site attribute variables before our model is over identified. Thus, we found that due to multicollinearity between the site attributes, the parameter estimates are sensitive to the combination of attributes included in our model. Nevertheless, the travel cost parameter estimate was stable and consistent regardless of the site attributes included in our model.

To further aid the interpretation of the results, we construct Table 2.6 that provides the marginal implicit prices for changes in site characteristics (using the estimates from Model 1). The marginal implicit price of a variable is calculated as a ratio of the variable's parameter estimate to the travel cost parameter estimate and represents the marginal rate of substitution between a site attribute and travel costs. Marginal implicit prices can be used to compare the relative importance of different site characteristics to travel costs. The marginal implicit price of $15.69 for *YARDWASTE* indicates that yardwaste acceptance has the highest impact on recycling visits compared to a one unit change in the other site attributes. *HOURS* has the lowest marginal implicit price per unit. The results suggest that a 20 hour increase in operating hours per week for a non 24 hour site has almost the same impact as accepting an additional type of recyclable. Similarly a change from the lowest site operating hours, 15, to 24 hour operation would have about the same effect as accepting an additional eight kinds of recyclables (a change in *NUMREC* of eight). The results also suggest that a change from zero to two types of commingled recyclables accepted has approximately the same impact as accepting 5 additional types of recyclables or having an additional 100 operating hours. While YARDWASTE has the largest effect for a one unit change in the variable, since it is a dummy variable the one unit change is akin to a change from its lowest value to its highest value. Considering the effect of a change from the lowest to highest value of *NUMREC,* a change of 17, when multiplied by its marginal implicit price, reveals that it has the largest overall effect of any of the site attributes over their respective ranges.

Table 2.6. Marginal implicit prices for changes in site characteristics

Variable	Marginal Implicit Prices
HOURS	\$0.07
NUMREC	\$1.36
COMING	\$3.48
YARDWASTE	\$15.69

2.5 Scenario Analysis and Policy Implications

In this section, we use the basic model to impute the probability of site visitation to the respective eight sites. The probability of visitation for each site is calculated by substituting the parameter estimates derived from our weighted model into the household weighted site choice probability function (equation 11) and summing it up across all respondents. Table 3 presents the probability of visitations in descending order, to all the drop-off sites.

Table 2.7. Probability of site visitation

Site name	Predicted probability of trip
Site 3	0.271
Site 2	0.209
Site 1	0.207
Site 5	0.101
Site 6	0.100
Site7	0.055
Site 8	0.044
Site 4	0.013

The model predicts that most recycling trips are taken to the Site 3 drop-off recycling site. The recycling site with the lowest probability of site visitation is

Site 4. The difference between the site with the highest and lowest probability of visitation is also very large. Given that a recycler makes a trip to a drop-off site, the probability of the recycler choosing to visit Site 3 is approximately 20 times larger than the probability of the recycler choosing Site 4.

Using the model we predict changes in visitation rates when a recycling site is closed. Table 2.8 displays the probability of site visits to remaining sites when one particular site is closed. The closed site in the table is indicated by a zero probability of visitation. A site closure will result in recyclers resorting to alternative sites, and they will substitute the closed site with its next best alternative. The next best alternative site might be a site that is closest in distance to the recycler or a site with similar attributes to the site that has been closed. Since we cannot know which site is each person's next best alternative, we report the predicted probability of site choice after the change. The best substitute for a closed site, on average, will experience the highest increase in probability of site visitation. The simulation results indicate that if we close Site 1, the site that experiences the highest increase in visitation probability is Site 5. This is probably because of the proximity between Site 5 and Site 1 although Site 5 lacks some of the attributes Site 1 has, such as the acceptance of yardwaste. Another site that receives an equally high increase in probability of visits when Site 1 is closed is Site 2. An explanation for this is the similarity in features between the two sites such as the acceptance of a wide variety of recyclables although the distance between the two sites is quite far.

Table 2.8. Probability of site visitation due to site closure

Site name	**Predicted probability of trip when a site is closed**							
	Policy 1 *Close Site 1*	Policy 2 *Close Site 2*	Policy 3 *Close Site 3*	Policy 4 *Close Site 4*	Policy 5 *Close Site 5*	Policy 6 *Close Site 6*	Policy 7 *Close Site 7*	Policy 8 *Close Site 8*
Site 1	-	0.337	0.274	0.210	0.243	0.234	0.220	0.210
Site 2	0.261	-	0.221	0.211	0.218	0.215	0.214	0.209
Site 3	0.313	0.297	-	0.273	0.297	0.304	0.285	0.299
Site 4	0.019	0.022	0.016	-	0.015	0.015	0.015	0.013
Site 5	0.154	0.120	0.156	0.103	-	0.119	0.109	0.104
Site 6	0.135	0.114	0.183	0.102	0.118	-	0.113	0.106
Site 7	0.071	0.066	0.084	0.057	0.063	0.068	-	0.057
Site 8	0.046	0.045	0.067	0.044	0.046	0.046	0.045	-

We also use the model to predict the changes in visits when we change the attributes of a recycling site. We create a hypothetical combination of good attributes for a recycling site: 24 hours of operating time, accepts 10 different types of recyclables, accepts two types of commingled recyclables and accepts yardwaste. One possible scenario is to improve the features of Site 6 to the hypothetical site attributes. Site 6 is a smaller and a less comprehensive site as compared to the popular sites such Site 1, Site 2 and Site 3. However, Site 6 is strategically located in the middle of all the eight sites, and it has the lowest mean distances for all respondents (see Figure 2.1). This simulation will indicate what happens to visitation patterns when we improve the attributes of Site 6. Alternatively, another possible scenario is to change the features of Site 8 to the hypothetical site attributes described above. Site 8 is one of the least popular sites mainly because of its location but also due to its attributes such as a low level of recyclables accepted and limited operating hours. Table 2.9 outlines the probability of site visitation to all eight sites under these two scenarios: changing the attributes of site 6, and changing the attributes of site 8.

Figure 2.1. Locations and mean distance (miles) for drop-off recycling sites

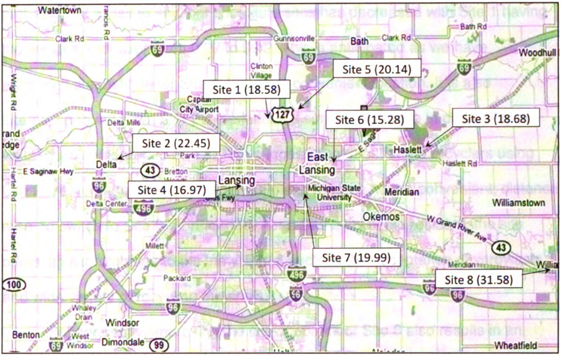

Table 2.9. Probability of site visitation after changes in site attributes

Site name	Predicted probability of a trip if the attributes of Site 6 are improved	Predicted probability of a trip if the attributes of Site 8 are improved
Site 1	0.122	0.193
Site 2	0.178	0.205
Site 3	0.164	0.230
Site 4	0.007	0.012
Site 5	0.050	0.090
Site 6	0.421	0.090
Site 7	0.024	0.049
Site 8	0.034	0.131

By improving the attributes of Site 6, the probability of visits to the recycling site has substantially increased from 0.10 to 0.42. On the contrary, the probability of a visit to all other substitute sites has decreased with Site 1 having the greatest reduction from 0.27 to 0.12. This is anticipated as we have enhanced a substitute for Site 1 at a more convenient location. It is also interesting to note that Site 2 experiences a smaller decrease in probability of visits when compared to Site 3. This suggests that most of the recyclers using Site 2 are from the Site 2 township itself, and it would not be convenient, distance wise, to switch to Site 6. Furthermore, for a Site 2 township resident, the site offers similar attributes to the 'new' Site 6 such as the acceptance of yardwaste and wide variety of recycling materials.

Subsequently, improving the site attributes of Site 8 also results in an increase in the probability of visit to the site. However, the increase is only from 0.03 to 0.13 which is not as large compared to our first scenario when we change the attributes of Site 6. Changing the attributes of Site 8 also did not result in large decreases in the probability of visits to other remaining sites. This implies that attributes alone are not enough to substantially increase visitation rates and a recycling site needs to be both conveniently located and equipped with comprehensive attributes to attract a large share of users.

2.6 Conclusions

There are only a few studies on drop-off recycling despite the wide implementation of drop-off programs across this country. This study addresses this gap by proposing a novel method to assess the demand for drop-off recycling sites. The use of a RUM model, which has been traditionally employed in transportation and recreation economics, is an appropriate and theoretically consistent way to analyze the demand for drop-off recycling sites in an urban setting with several substitute sites. The findings demonstrated that higher travel costs significantly reduce the probability of visiting a drop-off recycling site. This implies that the location of a site relative to where people live clearly affects site visitation. The findings also indicate that site-specific convenience-related attributes such as site operating hours, the number recyclables accepted, acceptance of commingled recyclables, and acceptance of yardwaste significantly affect which drop-off recycling sites get visited. However, some caution is warranted when interpreting the specific effects of individual site attributes (other than travel costs) due to our finding of potential multicollinearity between these attributes. Nevertheless, taken as a group, the site attributes were always highly significant in explaining site choices.

Given the significance of all these factors, policy makers should consider the influence of site location and site attributes when planning and designing facilities in order to maximize the use of drop-off recycling sites. Drop-off sites should be located in areas that are relatively near and accessible to a majority of the population. The results from the scenario simulation demonstrate that a site that is conveniently located will attract a high usage if equipped with convenience-related attributes such as a accepting a wide variety of recyclables and yardwaste. Our scenario simulation results also demonstrate that improving convenience-related attributes alone will not be sufficient to significantly increase site visits if the site is not strategically located.

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ESSAY 3. FACTORS INFLUENCING THE RATE OF RECYCLING: AN ANALYSIS OF MINNESOTA COUNTIES

3.1 Introduction

Annual municipal solid waste (MSW) generation in the United States has increased from 88 million tons in 1960 to approximately 251 million tons in 2006 (EPA, 2006). The escalating waste generation combined with concerns over landfill costs and availability of space have prompted regulators and policymakers to reform MSW policies at all levels, from the community to the state level. Waste management practices such as source reduction, recycling, and composting have been instituted in order to reduce materials from entering the waste stream.

A range of programs and policy instruments are available to policy makers for managing waste and recycling. Given the variety, analyses of the effectiveness of these practices are needed for improved policy decisions. Several studies have been conducted to understand the effects of various waste management policies on reducing waste and increasing the amount of recycling, and these studies have analyzed the impacts of policies on per capita waste generation and recycling demand. However, most policymakers evaluate the effectiveness of recycling and waste management programs by looking at improvements in the rate of recycling because the rate of recycling is able to capture movements in the amount of recycling and waste generation at the same time, as opposed to separate measurement of per capita quantities. In fact some states like New Jersey have regulations mandating minimum recycling or diversion rates. One of the key features of this study is that we analyze the impacts of different policies on recycling rates.

Another feature of this study is the use of time-series data on recycling rates. Most of the earlier studies on the effectiveness of recycling and waste management policies are based on cross sectional data analyses, and hence they are unable to incorporate dynamics of certain policy variables. Compared to these, the analysis in this paper uses county level data from Minnesota covering the period 1996 to 2004 and the panel nature of the data enables analysis of cumulative effects over time.

The broad objective of this research is to examine the factors that affect recycling rates in Minnesota counties by utilizing a set of panel observations of recycling and waste management policies, along with income and demographic variables. Specifically, this research analyzes the effectiveness of various recycling and waste management policy variables on county rates of recycling. The policy variables that we examine include: variable pricing for waste disposal, expenditures on recycling education, provision of curbside recycling services and drop-off centers, and enactment of recycling ordinances. Unique to this study, we account for the cumulative effects of the expenditure variable on recycling rate. We also investigate whether different recycling programs such as curbside and drop-off recycling act as complements or substitutes in increasing recycling rates by considering the interactions between the variables. Lastly, this research examines the effect of income and demographic characteristics such as age, education and population density on the recycling rate.

3.2 Literature Review

Household recycling and waste management literature can be divided into two broad classes; articles that use more comprehensive models incorporating the behavior of governments, firms, and consumers and articles focusing on consumer reactions to various pricing schemes (Linderhoff et al, 2001). Articles of the first type are mostly theoretical while those of the second type are mostly empirical. Earlier theoretical studies in this area began analyzing waste generation without including recycling. Wertz (1976) for example, develops an economic model to explain household's decisions regarding waste production. Households are assumed to maximize utility, which is a function of goods consumed and waste generated, subject to a budget constraint incorporating the cost of waste disposal that increases with waste generated. The model analyzes, among other variables, the impact of waste disposal unit-pricing and income on the quantity of waste generated. The analysis suggests that the quantity of waste generated decreases when the waste disposal fee increases, and waste generation increases with income.

The study by Wertz (1976) was extended by Jenkins (1993) by modeling both the residential and commercial sectors' demand for solid waste services and most importantly by including recycling as a waste reduction option. The household utility maximization model suggests that the level of household income, the prices of goods consumed, payments from recycling deposit items and waste disposal user fees will affect the demand for solid waste services. A firm profit maximization model is developed to derive the demand for commercial solid waste services. The model assumes that the cost of production increases with recycling activities but is mitigated by the increase in revenue from selling recyclables. The final analysis suggests that the demand for commercial solid waste services is a function that is decreasing in costs of production, increasing in the revenue from sales of recyclables, and the decreasing in the user fee for commercial solid waste services.

Saltzman, Duggal and Williams (1993) developed a theoretical framework for analyzing household waste generation and recycling. They adopted the model by Wertz (1976) and introduced recycling explicitly in the utility function. Unlike the study by Jenkins (1993), the recycling function of their study is more elaborate because it includes factors such as household's degree of ecological consciousness and the amount of time required to sort the recyclables from waste. Their study also derives comparative statics to examine the mixed impact of income on the household recycling effort. Hong (1999) adopted the household production function framework by Becker (1965) and Pollack and Wachter (1975) to develop a household solid waste generation and recycling function. He incorporated the time spent recycling in the utility function and derived the reaction functions for solid waste generation and recycling. He then developed a system of structural equations to investigate the interactions between household waste generation and recycling and found out that household recycling efforts are expected to increase as waste collection fee increases.

Kinnaman and Fullerton (2000) developed a theoretical model to derive the recycling and waste disposal demand function for a community, and then empirically estimated the impact of waste disposal fees and curbside programs on recycling and waste generation. Their paper established that the demands for waste disposal and recycling are functions of curbside recycling, price of waste disposal, mandatory recycling policies, deposit refund system for recyclables, ban on yardwaste disposal, income and demographic characteristics.

The empirical studies on recycling and waste management can be classified into two categories; the studies that utilize household level data (Fullerton and Kinnaman, 1996; Van Houtven and Morris, 1999; Hong, 1999; Hong and Adams, 1999; Linderhof et al, 2001) and the studies that utilize macro level data such as a community or county level data (Podolsky and Spiegel, 1998; Kinnaman and Fullerton, 2000; Johnstone and Labone, 2004; Callan and Thomas, 2006). Most of the empirical work using household level data studies the impact of garbage pricing on waste generation. Fullerton and Kinnaman (1996) utilize individual household data in Virginia to estimate the effect of a garbage unit pricing program on the weight of the garbage, the number of containers, the weight per can and the amount of recycling. They found that in response to unit pricing households reduced the number of garbage bags but not necessarily the weight of the garbage. They also found that there was an increase in the weight of recycling, but there was also an evidence of illegal dumping. They concluded the incremental benefit of the unit pricing program was small and outweighed by the administrative cost.

Van Houtven and Morris (1999) examined the implication of unit-based pricing on household waste generation in a waste demonstration project in Marietta, Georgia. Instead of paying a fixed collection fee, half of the participating households paid a fee for a reusable trash can and the other half paid for each trash bag collected. The data collected indicate that both the programs significantly reduced waste generation even after taking into account the increase in recycling. The bag program was also found to result in a larger reduction in waste generation compared to the can program. Hong (1999) studied the impact of unit pricing and aggressive recycling programs on solid waste generation and recycling by employing data from a large household survey from Korea. The results indicated that an increase in waste collection fee paired with aggressive recycling programs was more effective in reducing the waste disposal than an increase in collection fee without any recycling program. They also found that a weight-based unit pricing system was more effective in reducing waste compared to volume-based unit pricing as households tend to compact wastes to reduce charges in the latter form of pricing.

Hong and Adams (1999) studied the effect of disposal fee and household characteristics on recycling and waste generation by analyzing household level data from Portland, Oregon. They reported that an increase in the price of solid waste collection increased the demand for recycling, and they also found that an increase in the price of collection had a negative effect on the demand for waste disposal. Linderhof et al (2001) utilized a large household panel data from a Dutch municipality to analyze the effects of weight-based pricing on household waste collection. They concluded that weight-based pricing has a strong negative effect on the amount of waste collected. Podolsky and Speigel (1998) developed a theoretical model to derive the demand for municipal solid waste disposal and examine the effect of unit-pricing and household recycling on municipal solid waste disposed by using community-level data for 149 New Jersey municipalities. Unique to their study, the model assumed that households derive utility from the consumption of goods and incur disutility from recycling waste. The model suggests that the optimal level of waste generated will be at level where the marginal disutility of recycling equals the unit price of disposal. Their empirical evidence indicates that unit price significantly reduces the amount of solid waste disposed. They also hypothesized that recycling affects waste disposal through two components. The first is the non-price component which is the direct effect of recycling reducing the amount of solid waste as the two activities are substitutes. The second component captures the indirect effect of unit-pricing on waste disposal through changes in recycling. However, they found that only the non-price component of recycling significantly reduces waste disposal.

Most of the macro-level studies that we reviewed utilize cross-sectional recycling and waste management data. As mentioned above, Podolsky and Speigel (1998) in a study using community-level data for 149 New Jersey municipalities found that unit pricing significantly reduces the amount of solid waste disposal. Kinnaman and Fullerton (2000) derive a similar conclusion by analyzing cross-sectional data of more than 900 U.S communities. They also found that curbside recycling programs encourage recycling. The main contribution of the Kinnaman and Fullerton paper, besides having employed a relatively large dataset was to recognize the endogeneity of local government policy decisions. Unlike most of the previous studies that assume that policy variables such waste disposal pricing and provision of recycling facilities are exogenous; they argued in that these variables tend to vary with community attributes and household characteristics. Since public policies are usually responsive to the conditions in the local community, Kinnaman and Fullerton treat disposal pricing and implementation of curbside recycling as endogenous variables and correct the endogeneity by using a two-stage least square (2SLS) estimation method.

Johnstone and Labonne (2004) is one of the few waste management studies that has used a panel dataset in its analysis. This study analyzes the determinants of solid waste generation using the municipal solid waste, demographic and economic data of 30 Organisation for Economic Co-operation and Development (OECD) countries from 1980 to 2000. Adopting the framework proposed by Kinnaman and Fullerton (1997), their study models the demand for municipal solid waste services as a function of waste pricing and demographic characteristics such as average data on household size, number of children in a household, the number of working adults in a household and proportion of urban population. Due to in availability of the price data, they used population density and country dummies as proxies for waste disposal prices. It was argued that waste disposal pricing was reflected in the cost of disposal which was closely related to population density and the country itself. Their study found that household waste generation was relatively inelastic with respect to income and that urbanization increases waste generation.

In a more recent study, Callan and Thomas (2006) examine the demand for disposal and recycling services by utilizing cross-sectional data of 351 municipalities in Massachusetts. Similar to Kinnaman and Fullerton (2000), their study allowed for the endogeneity of garbage unit-pricing and the provision of curbside services, but their study differed by also allowing the demand for waste disposal and recycling to be simultaneously determined. In addition to variables for demographics, garbage pricing and curbside recycling, this study also incorporates an expenditure variable which measures state funded grants for recycling equipment and education. The results demonstrate that unit-pricing indirectly effects garbage disposal through increased recycling and that availability of curbside services reduces disposal demand. The results also indicate that communities with grant allocation for recycling education or equipment recycle significantly more than communities without any allocation. It was also found that household size and age are significant determinants for the demand for disposal service and education is a significant determinant of recycling.

3.3 Theoretical Framework

We adopt the utility maximization model proposed by Kinnaman and Fullerton (2000) but with some slight modifications to explain waste generation and recycling in order to derive the function for the rate of recycling. Similar to their approach, we begin by explaining household choices and then apply this framework to the county's policy choices.

Assume an economy in a county comprised of *N* identical households with utility functions represented by

$$U_i = U(x_i, E_i) \tag{1}$$

where x_i represents composite goods and services consumed by household *i* and E_i is the environmental quality that the household *i* perceives to enjoy. The environmental quality function is specified as follows

$$E_i = h(g_i, r_i; d_i) \tag{2}$$

where g_i is the amount of waste disposed and r_i is the amount of materials recycled by household *i*. The choice of the g_i and r_i in E_i is also dependent on a set of demographic characteristics, d_i. Substituting equation (2) into (1), we rewrite the utility function as

$$U_i = U(x_i, h(g_i, r_i; d_i)) \tag{3}$$

Each household maximizes utility subject the following budget constraint

$$x_i + p_g g_i + p_r r_i = m_i \tag{4}$$

where the price of composite goods x_i is normalized to unity, p_g is the price of waste disposal, p_r is the price of recycling and m_i is the total household income. Solving the utility maximization problem yields the following demand functions for waste and recycling:

$$g_i = g(p_g, p_r, m_i, d_i) \tag{5}$$

$$r_i = r(p_g, p_r, m_i, d_i) \tag{6}$$

The following equations outline the functions for the price of waste disposal and the price for recycling.

$$p_g = p_g(P, L, m_i, \alpha_i) \tag{7}$$

$$p_r = p_r(F, S, m_i, d_i) \tag{8}$$

The price of waste disposal for a household will factor in the disposal fee (P) imposed by the waste service provider as well as other costs associated with the time and effort required by the household to handle the waste. The time and effort costs are assumed to be functions of household income and demographic characteristics. The price of waste disposal is also affected by regulations that enforce recycling (L). Presence of regulations such as the ban of certain recyclables in the waste stream will directly increase disposal costs because of possible penalty.

The price of recycling for a household is mainly the time and effort costs of separating, storing, transporting and depositing the recyclables. Similar to waste, time and effort costs can be functions of income and demographic characteristics. Time and effort costs can also be affected by policy variables such as the types of recycling programs (F) and recycling education related expenditures (S). Recycling programs such as curbside recycling services and drop-off recycling centers will reduce the time and effort costs faced by households to recycle. Recycling education expenditures will help increase recycling awareness and will educate households on the importance and benefits of recycling. Recycling education will also expose households to the efficient methods of recycling and the availability of recycling facilities and this will indirectly help reduce the time and effort costs associated with recycling.

Substituting equations (7) and (8) into (5) and (6), we rewrite the waste and recycling demand functions as

$$g_i = g(P, L, F, S, m_i, d_i) \tag{9}$$

$$r_i = r(P, L, F, S, m_i, d_i) \tag{10}$$

We are able to derive the rate of recycling by using the information on waste and recycling, and the theory implies that the recycling rate function will have the same explanatory variables as in the waste and recycling demand functions. Recycling rate is defined as a percentage ratio of the weight of recycled waste to the total solid waste collected for disposal and incineration. (Lund, 2001).

Since we assume that households within each county have the same utility function, results aggregated at the county level will represent aggregate household level decisions. Thus, the recycling rate function of a county is written as follows

$$R_i = f(P_i, L_i, F_i, S_i, m_i, d_i) \tag{11}$$

We expect variable rate pricing to have a positive effect on recycling rate because in a variable pricing system, households will have to pay higher disposal charges when they produce more waste. This pricing system is expected to provide an incentive for households to increase recycling in order to reduce the amount of waste disposal. We also expect the presence of regulations that enforce recycling to increase the recycling rate. Mandatory recycling regulation forces people to recycle to avoid penalties, and this will increase recycling and reduce the amount of recyclables in the waste stream. County recycling programs are expected to increase recycling rate. Recycling programs such as curbside recycling pickup and drop-off centers facilitate recycling activities by making recycling more convenient for households. We expect programs such as curbside recycling and drop-off centers to have a higher impact on recycling rate when implemented together than when they are implemented separately. We expect recycling education expenditures to be positively associated with the recycling rate because they increase awareness and reduce costs.

We expect income to have a negative association with recycling rate. People with higher income generally consume more and tend to generate higher amounts of waste which leads to a lower rate of recycling. Also, when income increases the opportunity cost of recycling goes up and this can lead to a reduction in recycling. The county demographic variables are represented by age, education and population density. We expect age to be positively related to recycling as people who are older, especially retirees, tend to have more time to spend on activities such as recycling. This view is supported by the findings of previous studies that middle aged and older people are more likely to recycle (Vining and Ebreo, 1990; Meneses and Palacio, 2005; Saphores et al, 2006). We expect education to be positively associated with the rate of recycling. People with higher education are expected to be more aware of environmental issues which would encourage them to recycle. We expect population density to be negatively associated with recycling rate. Residences in high population density areas are usually smaller than those in low population density areas.

Since lack of space is one of the major inconveniences that discourage people to recycle, it is probable that high population density will lead to reduced recycling activities and increased waste generation, which results in an overall decrease in the rate of recycling.

3.4 Data and Variable Descriptions

The data used for this research are drawn from two different sources. The recycling and waste management data for this study are obtained from the Minnesota's SCORE database. Minnesota is among the pioneers of waste management reforms in this country. It began a statewide recycling effort as early as 1989 after the adoption of legislation based on the recommendation by the Governor's Select Committee on Recycling and the Environment (SCORE). The legislation provides state funding on waste reduction, recycling program management and household hazardous waste management. The waste management and recycling program in Minnesota is deemed to be one of the most successful state level programs in the United States considering the local government investments and public participation. According to a report in BioCycle magazine's survey 2006, Minnesota has a recycling rate of 43% and is ranked second in the nation after Oregon with a recycling rate of 45%.

The SCORE database compiles data from annual surveys of waste management and recycling in all Minnesota counties. The SCORE survey is administered by the Minnesota Pollution Control Agency (MPCA) and is completed by county solid waste officers. The survey collects information on MSW generated, materials collected for recycling, solid waste collection system, recycling programs and management, waste and recycling revenue and expenditure, source reduction programs and other MSW policy initiatives. We augment the recycling and waste management data with income and demographics data for Minnesota counties from the US Census Bureau database covering the period from 1996 to 2004. The two data sources combine to create a balanced panel of complete variables for 774 observations representing 86 counties in Minnesota. The variables selected for our analysis are listed and defined in Table 1.

Table 3.1. Definitions of variables

Variable	Definition
Rate	Residential recycling rate per annum (percentage)
VarP	1 if county implements variable rate pricing structure (0 otherwise)
Ordin	1 if county has an ordinance that requires residences to recycle (0 otherwise)
Curb	Percentage of population with access to curbside recycling
Drop	Number of drop-off recycling centers per 1,000 persons in the population
EduExp	Cumulative (3 years) recycling education expenditure per capita ($)
Inc	Income per capita ($)
Age	Median age
Educ	Percentage of population with 4 or more years of college education
Den	Population density per square mile

Recycling rate is computed by dividing the amount of residential recycling by the amount of total waste generated in the county[3]. *VarP* is our waste disposal pricing variable which is a dummy variable representing whether the county had

[3] Total waste generated is the summation of amount of recycling and MSW landfilled.

a variable pricing scheme or not. The survey did not collect information on the actual unit prices charged. In contrast to the studies that use community level data, we use county data which with aggregate information for several different townships or communities making it difficult to deduce the county waste price as the prices usually vary across communities. Furthermore, in most cases variable pricing meant two or three tier pricing for different container sizes, and this type of pricing is not a true unit pricing such as "by the bag" pricing of waste disposal[4] because the marginal costs of an additional unit of waste in a tiered pricing scheme are zero within a tier. Given these considerations, it is reasonable to operationalize variable pricing as a dummy variable. We expect the presence of *VarP* to be endogenously determined in a county.

Our recycling regulation variable is represented by *Ordin* which indicates whether a county enacts recycling ordinances to make recycling compulsory for the residents. We use *Curb* and *Drop* to represent recycling programs in a county. *Curb* measures the percentage of county's population with access to curbside recycling, and *Drop* measures the number of drop-off recycling facilities available per 1,000 persons in the county. We also expect both *Curb* and *Drop* to be endogenous. The county's recycling education expenditure variable is represented by *EduExp* which is the three-year cumulative recycling education expenditure for each county. Unlike previous studies, we use cumulative expenditures instead of current expenditure because we believe that expenditure on education has cumulative effects on recycling rate. The recycling awareness

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[4] This information on the types of variable pricing was obtained through telephone interviews with Minnesota EPA officers and waste management officers from several counties.

created from previous year's education will still have an impact on the current year's recycling activities. We are also able to avoid the potential endogeneity problem of an expenditure variable by using cumulative expenditure in our model. The income and demographic variables are represented by *Inc*, *Age*, *Educ* and *Den*. Table 2 provides the descriptive statistics of the variables in our model.

Table 3.2. Summary statistics of variables

Variable	Mean	Std. Deviation	Min	Max
Rate	16.00	6.71	1.55	40.18
Inc	24704	4518	16379	45565
Age	38.10	3.69	29.00	48.10
Educ	11.73	0.05	4.44	39.61
Den	121.77	417.63	3.21	3348.21
VarP	0.82	0.39	0.00	1.00
EducExp	0.37	0.52	0.00	4.77
Curb	53.42	27.27	0.00	100.00
Drop	0.67	0.68	0.00	4.19
Ordin	0.23	0.42	0.00	1.00

n=774

The SCORE survey data indicates that the mean recycling rate for Minnesota is 16% and the rate varies from 1.55% to 40.18%[5]. Figure 3.1 and 3.2 illustrate the trend in waste generation and the amount of residential recycling for Minnesota from 1996 to 2004.

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[5] The calculated mean is lower than mean published in the BioCycle magazine because we excluded recyclables such as used tires that were based on estimates

Figure 3.1. Mean per capita municipal solid waste in Minnesota (1996-2004)

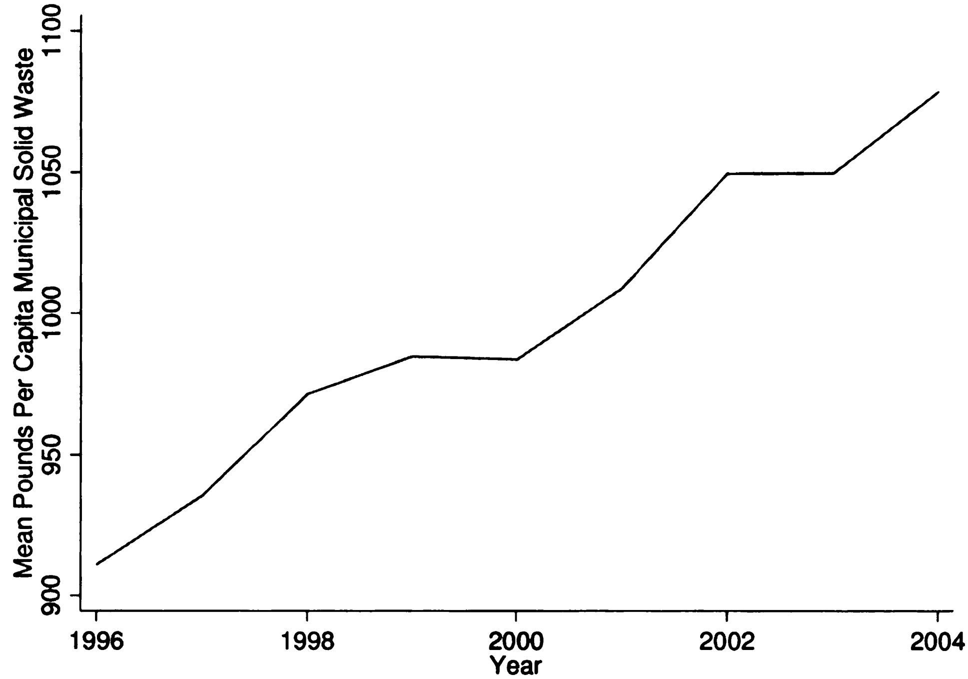


Figure 3.2. Mean per capita residential recycling in Minnesota (1996-2004)

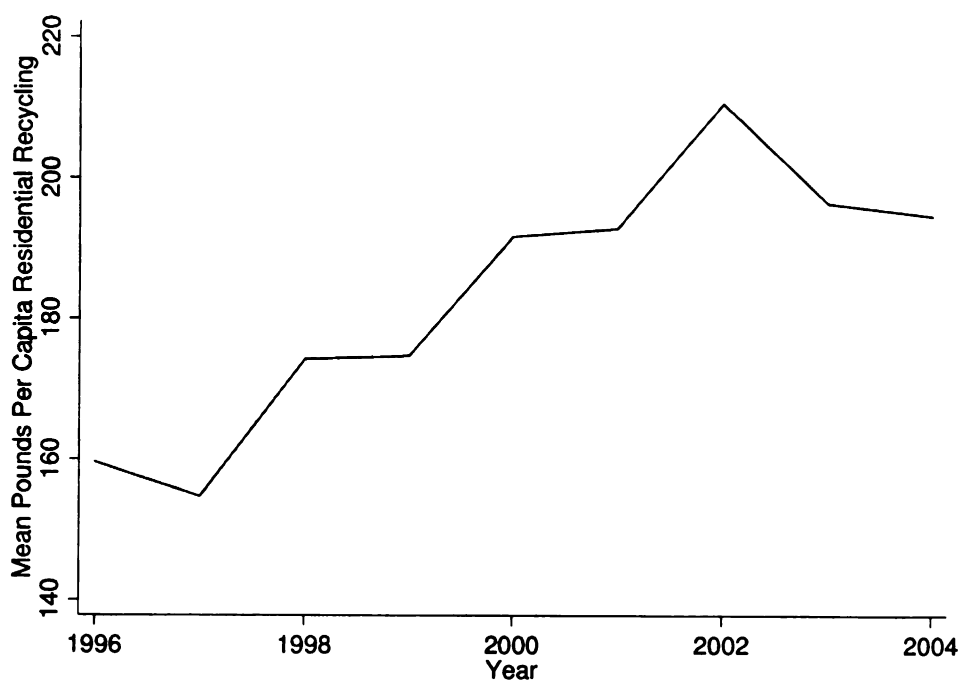
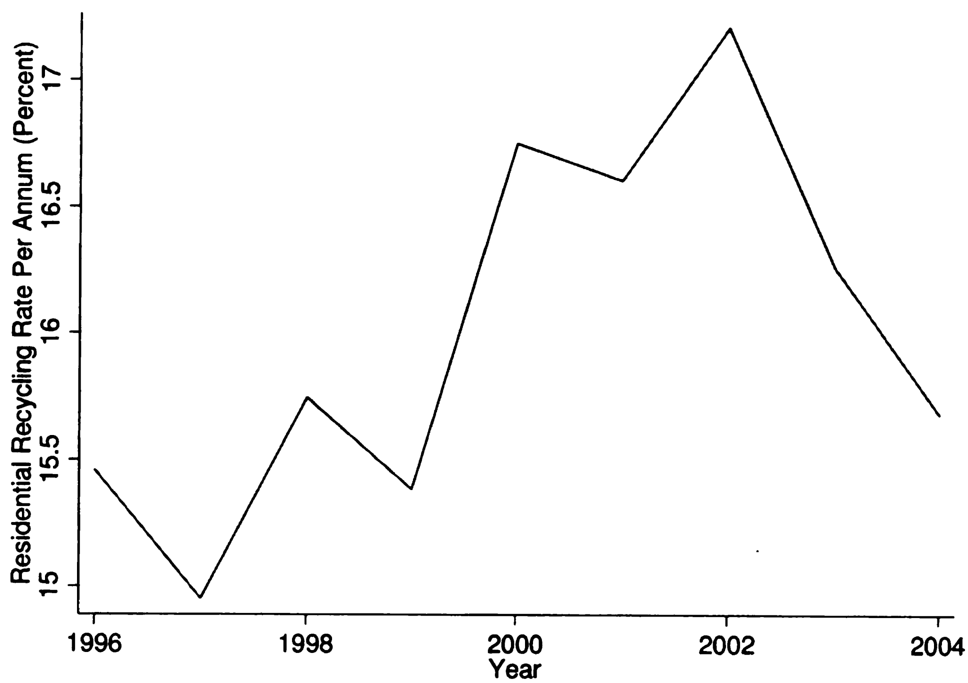


Figure 3.3 illustrates the residential recycling rates from 1996 to 2004. It is evident from Figure 3.3 that generally there is an increasing trend in mean recycling rate with slight fluctuations from 1996 to 2002. The rate of recycling then decreases from 17% in 2002 to approximately 15% in 2004. This occurrence can be explained by the steadily increasing trend in per capita waste generation (Figure 3.1) and the slight decrease in per capita recycling from 2002 to 2004 (Figure 3.2).

Figure 3.3. Mean residential recycling rate in Minnesota (1996-2004)



Eighty-nine percent of the counties in our data adopt variable pricing structure for waste disposal and 23% have enacted ordinances making recycling compulsory for residents. The mean expenditure for recycling education spent on a person is 37 cents and it varies from zero to $4.77. The mean percentage of population access to curbside recycling services is 53.42% and the mean number of drop-off recycling centers per 1,000 persons in the population is 0.67.

The US Census Bureau data indicates that the income and demographic characteristics of the counties in Minnesota vary considerably. The mean per capita income for Minnesota counties is $24,704, and the county average per-capita income ranges from $16,379 to $45,565. The median age per county varies from 29 years old to approximately 48 years old. The mean percentage of population with a bachelor's degree or higher is approximately 11.74%, and it varies from 4.44% to 39.61%. The mean population density is 121.77 persons per square mile, and the density varies from as low as 3.41 persons per square mile to 3,348.21 persons per square mile.

3.5 Econometric Methods and Results

We model the county recycling rate as a function of waste management policy, income and demographic variables. The linear econometric specification of the county recycling rate function is specified as follows

$$\begin{aligned} Rate_{it} &= \beta_0 + VarP_{it}\beta_1 + Ordin_{it}\beta_2 + Curb_{it}\beta_3 + Drop_{it}\beta_4 \\ &\quad + CurbDrop_{it}\beta_5 + EducExp_{it}\beta_6 + Inc_{it}\beta_7 + Age_{it}\beta_8 \\ &\quad + Educ_{it}\beta_9 + Den_{it}\beta_{10} + Time_t\beta_{11} + a_i + u_{it} \end{aligned} \tag{12}$$

$Time_t$ is the dummy variable for each year except first year, and a_i and u_{it} are the components for the unobserved disturbance for county *i* at time *t*. Since we have a panel data, we are able to exploit the repeatability of the data by decomposing the unobserved disturbance to allow for a county-level effect. Thus, a_i represents the unobserved county-level effect and u_{it} is the idiosyncratic error that changes over time for each county. The dummy variables for years will allow for exogenous statewide changes in recycling rate over time.

We estimate the model using the random effects method as we assume that the unobserved effect is uncorrelated with each of our explanatory variables. We use the Hausman's (1978) specification test to confirm that random effects is the appropriate specification for the county specific unobserved effects in our model as opposed to fixed effects. The test result indicates that unobserved effects are adequately modeled by random effects, and the model produces efficient and consistent estimators. Table 3 outlines the results of our regression models; pooled-OLS, random effects model, random effects model with instrumental variables (IV). The pooled OLS model is estimated for comparison basis as the random effects model assumes strict exogeneity between the explanatory variables and the disturbance term. If this assumption fails, pooled OLS will produce more consistent estimators.

Table 3.3. Determinants of the annual recycling rate in Minnesota counties

(Dependent variable = Residential recycling rate per annum)						
	Pooled-OLS		Random-Effects		IV Random-Effects	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
VarP	0.315	0.576	1.623	0.923*	4.193	2.210**
Ordin	4.151	0.569***	2.969	1.078***	2.108	1.090**
Curb	0.037	0.014***	-0.011	0.02	0.008	0.012
Drop	1.274	0.620**	0.934	0.765	-0.684	0.484
CurbDrop	0.001	0.013	0.026	0.015*	0.022	0.010**
EducExp	-0.534	0.435	0.747	0.477	0.816	0.505*
Inc	-0.0002	0.0001**	-0.0001	0.0001	-0.0002	0.0001*
Age	0.38	0.076***	0.229	0.148	0.445	0.141***
Educ	0.151	0.064**	0.136	0.11	0.129	0.114
Den	-0.001	0.001	-0.001	0.001	-0.001	0.001
Year Dummies	Yes		Yes		Yes	
Constant	0.262	3.379	4.956	5.341	-3.127	5.850
N	774		774		774	
R-squared	0.206		0.167		0.173	

$^{***}\alpha < 0.01$, $^{**}\alpha < 0.05$, $^{*}\alpha < 0.10$

The pooled OLS results suggest that age and higher education have significant positive contributions to the rate of recycling. The results also suggest that an increase in income marginally reduces the rate of recycling where a 1,000 dollar increase in annual income per capita will reduce the rate of recycling by 0.2 percentage point. Our pooled OLS model did not address the endogeneity problem of any of the policy variables. The policy variables that are significant in this model are *Curb*, *Drop* and *Ordin*. For this model, an increase in access to curbside recycling improves the rate of recycling -- a 1 percentage point increase in access increases recycling rate by 0.04 percentage point. Adding one recycling drop-off center per 1,000 populations was also found to increase recycling rates by 1.28 percentage points. The results also indicate that having a county recycling ordinance will increase the rate of recycling by 4.16 percentage point.

The random effects model without the endogenous policy variables has a lower explanatory power than the pooled model, and we find that income, age and education are not significant in this model. However, in this model *VarP* significantly affects the rate of recycling. The implementation of a variable pricing (*VarP*) structure on waste disposal charges is suggested to increase recycling rate by 1.62 percentage points. *Ordin* remains significant in this model but *Curb* and *Drop* are no longer significant. Nevertheless, the interaction variable *CurbDrop* is significant in this model. This indicates that curbside and drop-off recycling are able to increase the rate of recycling when implemented together.

Similar to the pooled OLS, our random effects model did not account for potential endogeneity of the policy variables.

The third model corrects for endogenous policy variables. We identify endogenous variables in our model by conducting endogeneity tests. The test is conducted by first estimating a reduced form OLS regression for the potentially endogenous variables. We regress these variables against all exogenous variables in our main equation (equation 12), together with other exogenous variables that do not appear in the main equation but we believe are correlated with the endogenous variable. We then obtain the residuals from our reduced form regression and use it as explanatory variable in an OLS regression of our main equation. We conclude that a variable is endogenous if the reduced form residual is found to have a significant coefficient in the main regression (Wooldridge, 2006). The test found that *VarP*, *Curb* and *Drop* are endogenous. We correct for endogeneity of *VarP* by using the predicted value from its reduced form regression (see Appendix 3: Table A3.1). We instrument for *Curb* and *Drop* with its one-year lagged variables. The choice of one-year lagged variables for *Curb* and *Drop* as the instruments is appropriate because we believe that the previous years' curbside recycling services and drop-off centers are exogenous to the current year's decision on the amount of recycling and waste generated in a county.

Correcting for endogeneity slightly improves the explanatory power of our random effects model, evident from the increase in R-squared from 0.167 to 0.173. *VarP*, *Ordin* and *EducExp* are significant in this model. We found variable price (*VarP*) to have a bigger impact on increasing the rate of recycling after correcting for endogeneity. Implementation of variable pricing structure on waste disposal was found to increase the recycling rate by 4.19 percentage points in the IV-random effects model as opposed to only 1.62 percentage points in the random effects model without endogeneity corrections. The coefficient for *EducExp* suggests a dollar increase in per capita cumulative education expenditure will increase recycling rate by 0.82 percentage points. Income and age are found to be significant in this model with the expected signs.

3.6 Conclusions

The rate of recycling is an important indicator that is widely used by policy makers to assess the level of recycling activities in a community, county or state. This study examines the effect of policy, income and demographic variables on the rate of recycling in Minnesota counties. After accounting for random effects and endogenous policy variables, our results demonstrate that variable pricing of waste disposal significantly increases the rate of recycling. This confirms the previous findings from cross-sectional studies that variable pricing is an effective policy tool for increasing the amount of recycling and reducing waste generation. Our findings also indicate that regulations can be an effective means of increasing recycling. We found that the enactment of recycling ordinances making residential recycling mandatory increases the rate of recycling.

It is also interesting to note that curbside recycling services and drop-off centers are effective in increasing the rate of recycling when implemented together as a recycling program. Curbside and drop-off recycling were found to be insignificant in improving the rate of recycling if they are implemented separately. Educating the public on recycling was also found to be an increase recycling rate. The findings showed that the cumulative expenditure on recycling education increased recycling rate, at the 10% level of significance. Spending one dollar per person per year will increase the rate of recycling by approximately 2 percent.

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CONCLUSIONS

The first two essays in this dissertation contribute to the current body of recycling and waste management literature by studying drop-off recycling behaviors and demand. The success of a drop-off recycling program is largely dependent on the participation of the public, and the first essay helps us to understand the profile of people who utilize drop-off recycling sites including the underlying factors influencing their usage. The results from this essay indicated that drop-off site utilization was influenced by demographic factors such as age, education, income and household size. This essay also concluded that attitudinal factors affect drop-off site visits. Utilization of drop-off sites increased for recyclers that feel recycling is a convenient activity and also for those that are more familiar with a recycling site. These findings signal the importance of promoting recycling facilities such as drop-off sites to encourage recycling activities.

The results from the second essay suggest that the demand for drop-off recycling sites is affected by the site location and the site specific characteristics. Drop-off sites that are relatively near and accessible to a majority of the population are found to receive higher visits than sites that are less strategically located. Convenience-related site characteristics such as site operating hours, the number of recyclables accepted, acceptance of commingled recyclables and yardwaste are found to increase site visits. However, improving convenience-related characteristics alone is not sufficient to increase recycling site visits if the site is not strategically located. Therefore, to increase utilization, policymakers should consider both location and facility characteristics before constructing a drop-off recycling facility.

The third essay in this dissertation examined the effects of policy, income and demographic variables on the rate of recycling in Minnesota counties. The findings demonstrate that variable pricing of waste disposal and the enactment of a mandatory recycling ordinance significantly increase the rate of recycling. The results suggested that curbside recycling services and drop-off recycling sites were effective in increasing the rate of recycling only when implemented together. This essay also found some evidence that expenditures for public education about recycling increased a county's recycling rate.

APPENDIX 1:
Survey Instrument (Essays 1 & 2)

HOUSEHOLD RECYCLING DEMAND SURVEY
Interview Version

Site Name: ______________________________

Date: ______________________________

Enumerator: ______________________________

Introduction

My name is [NAME] and I am a student at Michigan State University. I am currently working on a survey to study household recycling. In this survey we would like to know your experience as a recycler and your views with regard to recycling and the environment. Your input is important because it will help us learn more about household recycling demand and behavior as well as understand what can be done to improve household recycling activities. This interview should take around 10 minutes to complete.

Consent Statement

By continuing with this interview, you indicate your voluntary consent to participate in this study and have your answers included in the project data set. Your participation is voluntary. Your refusal to participate in or to withdraw from the study carries no penalty or loss of any benefits. You are free to not answer any of the questions that we will ask you. However, we hope that you will agree to answer the questions, as your answers are very important to this study. Answers are anonymous, and we will keep your individual views entirely confidential. Your privacy will be protected to the maximum extent allowable by law. If you have any questions or comments please contact me and if you have any questions concerning your rights as a survey participant, please contact the Director of the Human Research Protection Program in MSU.

Hand out contact details.

Your Recycling Activities

Please check ☑ the appropriate box or write in your answers where appropriate.

1. About how many times have you been to this site in the past **ONE YEAR**? ________
(skip Question 2 if answer is 0)

2. About how many times have you been to this site in the past **THREE MONTHS**?
____

3. Is your driving today for the sole purpose of recycling?
☐ YES (*skip Question 4*)
☐ NO

4. What percentage of your driving on this trip today would you attribute to recycling?
____________%

5. (*Record the make and model of the respondent's vehicle. If unsure, ask the respondent.*)

Make ____

Model ____

What is your vehicle year? __________

6. What are the **material(s)** that you **recycle** at this site? (*Check the relevant box(es) and write down the material(s) that is(are) mentioned but not listed*)
☐ Newspaper
☐ Cardboard
☐ Steel Cans
☐ Aluminum
☐ Clear Glass
☐ Brown Glass
☐ #1 PETE Plastic
☐ #2 Plastic Milk Jugs
☐ #2 Colored Plastic Jugs
☐ Magazines
☐ Office Papers
☐ Mixed Papers
☐ Junk Mail
Other Material(s)
____

7. Approximately how much time did you spend sorting the recyclables you brought in today? ______________

8. Why did you choose to recycle at this site? Is it.....(*read all the options below and check the answer – the respondent can have more than one reason*)
   - ☐ Because it is located near my residence
   - ☐ Because of the operating hours
   - ☐ Because of types of recyclables accepted
   - ☐ Because the site is well maintained and organized

   Do you have any other reasons for visiting this site:

   ____

   ____

9. Are you aware of other drop-off sites besides this one?
   - ☐ YES
   - ☐ NO (*skip Question 11*)

10. Can you name the site or sites that you are aware of? (*Use map to help respondents identify the sites (ignore the site respondent is currently at). Ask the respondents about the number of visits for the sites they have identified*)

Site Name	*Check if* ***Aware***	*Number of visits in the past* ***<u>ONE YEAR</u>****?*	*Number of visits in the past* ***<u>THREE MONTHS</u>****?*
(1) Site 1			
(2) Site 4			
(3) Site 5			
(4) Site 6			
(5) Site 2			
(6) Site 3			
(7) Site 7			
(8) Site 8			
Other (specify):			

11. Do you **recycle** at your **residence**? For e.g. **curbside recycling** services at your property or other types of recycling services at your dormitory or apartment

☐ YES

☐ NO (*go to Question 15*)

12. What are the **material(s)** you **recycle** at your **residence**? (*Check the relevant box(es) and write down the material(s) that is(are) mentioned but not listed*)

☐ Newspaper

☐ Cardboard

☐ Steel Cans

☐ Aluminum

☐ Clear Glass

☐ Brown Glass

☐ #1 PETE Plastic

☐ #2 Plastic Milk Jugs

☐ #2 Colored Plastic Jugs

☐ Magazines

☐ Office Papers

☐ Mixed Papers

☐ Junk Mail

Other Material(s) ____________________

13. How **satisfied** are you with the **recycling** service at your **residence**? (*Read the options and check the answer*)

☐ Very Satisfied

☐ Satisfied

☐ Indifferent

☐ Unsatisfied

☐ Very Unsatisfied

14. How are you charged for the waste collection service at your residence? (*Read the options and check the answer*)

☐ Fixed Fee for e.g. a flat charge for any volume of trash

☐ Incremental Fee for e.g. a variable charge according to the number of trash bags or the size of trash bin

☐ Included in Taxes or Rent

☐ No Charge

☐ Don't Know

Your Opinions on Recycling and the Environment

15. Please indicate the extent to which you agree or disagree with the following statements, taking into consideration your **recycling experiences.** The scale ranges from Strongly Agree, Agree, Neither Agree nor Disagree, Disagree and Strongly Disagree.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
For me, household recycling is a difficult task.					
I do not have enough time to sort the materials for recycling.					
I do not have enough space to store the materials for recycling.					
The recyclables that I store attract pests.					
I am familiar with the recycling facilities in my area.					
I am familiar with the materials accepted for recycling in the recycling facilities in my area.					
My neighbors expect me to recycle household materials.					
My friends expect me to recycle household materials.					
My family expects me to recycle household materials.					
I feel good about myself when I recycle.					

16. Based on your **knowledge** and **opinion** about **recycling** and the **environment**, please indicate your level of agreement with each of the following statements. The scale ranges from Strongly Agree, Agree, Neither Agree nor Disagree, Disagree and Strongly Disagree.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Recycling is a major way to reduce pollution.					
Recycling is a major way to reduce wasteful use of land for landfills.					
Recycling is a major way to conserve natural resources.					
Recycling will improve environmental quality.					

17. Based on what you **believe** about the **contribution** of your **recycling activities** to the **environment**, please indicate your level of agreement with each of the following statements. The scale ranges from Strongly Agree, Agree, Neither Agree nor Disagree, Disagree and Strongly Disagree.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
I believe that my recycling activities will help reduce pollution.					
I believe that my recycling activities will help reduce wasteful use of land for dumps.					
I believe that my recycling activities will help conserve natural resources.					
I believe that my recycling activities will help improve environmental quality.					

Questions about You

18. (Check the respondent's gender)
    - ☐ Male
    - ☐ Female

19. In what year were you born? 19______

20. Which of the following best describes the highest level of education you have completed? Would you say....(*Read the options and check the answer*)
    - ☐ some High School
    - ☐ High School or GED
    - ☐ Vocational or Trade School
    - ☐ Two Year Degree
    - ☐ Four Year Degree
    - ☐ Graduate School (e.g. MS, PhD, MD)

21. Which of the following best describes your employment situation? (*Read the options and check the answer*)
    - ☐ Employed Full Time
    - ☐ Employed Part Time
    - ☐ Unemployed
    - ☐ Retired
    - ☐ At Home Parent
    - ☐ Student

22. What was your annual household income before taxes in 2005?
    $____________________
    (*If respondent is reluctant to reveal exact income proceed to question A.*)

    A. The median household income in Michigan is around $45,000. Which of the following best describes your income level?
       - ☐ below $45,000 (*proceed to B*)
       - ☐ $45,000 and above (*proceed to C*)

    B. Is your household income less than $25,000?
       - ☐ YES
       - ☐ NO

    C. Is your household income more than $75,000?
       - ☐ YES (*proceed to D*)
       - ☐ NO

    D. Is your household income more than $100,000?
       - ☐ YES
       - ☐ NO

23. What is your marital status? (*Read the options and check the answer*)
☐ Single
☐ Married/ Living with partner
☐ Divorced/ Widowed/ Separated

24. How many persons are living in your household (including yourself)? __________
(go to Question 29 if answer is 0)

25. How many children under 18 years old are living in your household? __________
(go to Question 29 if answer is 0)

26. How many children under 6 years old are living in your household? __________

27. What extent would you agree or disagree with the following statement:
Your child or children play an important role in influencing you to recycle.
☐ Strongly Agree
☐ Agree
☐ Neither Agree nor Disagree
☐ Disagree
☐ Strongly Disagree

28. Do you or any member of your household belong to any environmental organization?
☐ YES
☐ NO

In this study, we are trying to measure your driving distance to a recycling site. It is important that we know where you live (or the nearest street intersection from your residence) so that we could accurately measure your driving distance. Would you be willing to share your address with us?

29. Where do you live?

Street ____________________

City ____________________

Zip Code ____________________

~ End of the survey ~

APPENDIX 2:
Tables (Essays 1 & 2)

Table A2.1. Attributes of drop-off recycling sites

Site name	*HOURS*	*NUMREC*	*COMMING*	*YARDWASTE*
Site 1	168	9	0	1
Site 2	15	20	2	1
Site 3	35	12	1	1
Site 4	168	3	1	0
Site 5	168	15	2	0
Site 6	168	10	2	0
Site 7	168	12	0	0
Site 8	35	6	1	1

Table A2.2. Interview schedule

Visitation Time	Recycling Site
Week 1, Sat 3 to 6	Site 5
Week 1, Sun 9 to 12	Site 1
Week 1, Sun 3 to 6	Site 6
Week 1, Mon 3 to 6	Site 6
Week 1, Tue 9 to 12	Site 7
Week 1, Tue 3 to 6	Site 7
Week 1, Wed 3 to 6	Site 4
Week 1, Thu 9 to 12	Site 6
Week 1, Thu 3 to 6	Site 3
Week 1, Fri 9 to 12	Site 8
Week 1, Fri 3 to 6	Site 5
Week 2, Sat 3 to 6	Site 1
Week 2, Sun 9 to 12	Site 4
Week 2, Sun 3 to 6	Site 5
Week 2, Mon 3 to 6	Site 5
Week 2, Tue 9 to 12	Site 6
Week 2, Tue 3 to 6	Site 4
Week 2, Wed 3 to 6	Site 1
Week 2, Thu 9 to 12	Site 3
Week 2, Thu 3 to 6	Site 4
Week 2, Fri 9 to 12	Site 1
Week 2, Fri 3 to 6	Site 3
Week 3, Sat 3 to 6	Site 3
Week 3, Sun 9 to 12	Site 7
Week 3, Sun 3 to 6	Site 7
Week 3, Tue 9 to 12	Site 2
Week 3, Wed 3 to 6	Site 2
Week 3, Thu 9 to 12	Site 8
Week 4, Tue 9 to 12	Site 2
Week 4, Wed 3 to 6	Site 2
Week 4, Thu 9 to 12	Site 8

Table A2.3. Distribution of cars according to sites

Site Name	Cars	Percentage
Site 2	202	35.19%
Site 1	146	25.44%
Site 3	113	19.69%
Site 5	50	8.71%
Site 4	29	5.05%
Site 6	26	4.53%
Site 8	5	0.87%
Site 7	3	0.52%

APPENDIX 3:
Probability Estimation of Variable Pricing Structure (Essay 3)

Table A3.1 presents the results for the logit estimation of the probability to implement variable pricing for waste disposal services in Minnesota counties. The exogenous variables not estimated in the main recycling rate equation (Chapter 3: Equation 12) are *Yard* and *RecExp* respectively. *Yard* represents a dummy variable for the ban on landfilling of yardwaste and *RecExp* represents the county recycling capital and operating expenditure.

Table A3.1. Logit estimation of the probability to implement variable pricing structure

(Dependent variable = *VarP*)		
	Coefficient	**Std. Error**
Inc	-0.00003	0.00004
Age	-0.112	0.038***
Educ	0.020	0.031
Den	0.005	0.003*
Ordin	0.650	0.262**
EduExp	0.262	0.237
Yard	2.585	0.500***
RecExp	0.075	0.021***
Year Dummies	Yes	
Constant	2.653	1.630*
n	774	
Pseudo R-squared	0.11	
Log-likelihood	-329.553	

***α < 0.01, **α < 0.05, *α < 0.10