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Statistisk sentralbyrå

Julie L. Hass

Household recycling rates and solid waste collection fees

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Statistisk sentralbyrå • Statistics Norway
Oslo–Kongsvinger 1997

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Standardtegn i tabeller	Symbols in tables	Symbol
Tall kan ikke forekomme	Category not applicable	.
Oppgave mangler	Data not available	..
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Tall kan ikke offentliggjøres	Not for publication	:
Null	Nil	-
Mindre enn 0,5 av den brukte enheten	Less than 0.5 of unit employed	0
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Foreløpige tall	Provisional or preliminary figure	*
Brudd i den loddrette serien	Break in the homogeneity of a vertical series	—
Brudd i den vannrette serien	Break in the homogeneity of a horizontal series	|
Rettet siden forrige utgave	Revised since the previous issue	r

Abstract

Julie L. Hass

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Understanding the factors that influence household recycling rates could point to ways that these recycling rates could be increased. Statistics Norway has had two country-wide surveys of the municipal solid waste system (1992 and 1995). These statistics are used to analyze the relationship between household recycling rates and the garbage collection fee levels. A number of other factors such as population density, centrality, municipal income and expenses, availability of a source separation collection system to the households, and time that a curbside collection system was introduced, are also included as a part of the analysis. Linear regression is used to identify the relationships.

The main conclusion of this study is that there is no relationship between the current levels of solid waste collection fees and the amount of material collected for recycling from households. The only variables which were found to be significantly related to the recycling rates of households were the length of time that a municipality had a system for curbside collection of paper and the closeness of the municipality to major cities. But these regression models only explain between 25 and 31 percent of the variation in the recycling rate data. So although there is a significant relationship between the variables, the models are not adequate explanations of the recycling rates. There are other factors which were not able to be identified that are influencing the recycling rate variables to a large degree.

Keywords: Garbage, fees, recycling, environment

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Project title: Gjenvinning og gebyrer i kommunal avfallshåndtering
Project number: 113699/720

Sammendrag

I 1995 leverte husholdningene 1,26 millioner tonn avfall. Av dette ble 18 prosent levert videre til materialgjenvinning. Miljømyndighetene ønsker at mer avfall leveres til gjenvinning, men spørsmålet er hvordan dette kan oppnås.

Kunnskap om effekt og kostnader ved tiltak er alltid viktig. I denne sammenheng er det viktig å avdekke om tiltak for økt gjenvinning vil medføre økte kosnader for abonnentene. På den annen side har det vært en diskusjon om å bruke høyere gebyr for å stimulere til økt gjenvinning. Denne analysen er en undersøkelse relatert til dette temaet. Data fra den kommunale avfallsundersøkelsen fra 1995 danner basis for analysen og lineær regresjon brukes som metode.

To typer av variabler er benyttet i analysen. Variabelen som blir forsøkt forklart, gjenvinningsraten, reflekterer individuell handling. Alle andre variabler som er tilgjengelige i denne undersøkelsen er strukturelle variabler fra den enkelte kommune.

Analysen av tallene er foregått ved regresjonsanalyse. Problemet med denne type data er imidlertid at noen få avvikende observasjoner i stor grad definerer resultatene av analysen. Eksempelvis varierer total mengde gjenvunnet materiale og totale inntekter av avfallsgebyrer mye fra kommune til kommune. Dette avhenger av flere faktorer, men befolkningsmengden er særlig framtredende. For å forhindre at resultatene skulle bli alt for avhengig av organiseringen av avfallshåndtering og gjenvinning i noen få, store kommuner, er gjenvinningsraten definert enten i prosent av total mengde avfall eller som mengde pr. person. Ved å bruke personrater eller andel av totalmengder, unngås problemet med at verdiene fra de store byene dominerer analysen.

Det var forventet at det ville bli funnet en sterk sammenheng mellom kommunale gebyrinntekter per person og totale kostnader (FDV- og kapitalkostnader). Etter Miljøverndepartementets forskrifter skal ikke den enkelte kommune ha en gebyrinntekt som er større enn årskostnadene. Det ville derfor være naturlig å forvente en tydelig sammenheng mellom inntekt og kostnad. En slik sammenheng ble da også funnet (se fig. 3.3).

Det ble ikke funnet en klar sammenheng mellom gjenvinning og gebyr. Ulike deler av datamaterialet ble analysert for å se om geografiske forhold eller befolkningstetthet kunne være faktorer som influerte på resultatene, men alle analyser med de to variablene var negative (se 4.1). Hovedkonklusjonen blir derfor at det ikke finnes noen tydelig sammeneng mellom størrelsen på kommunenes gebyrnivå og mengde avfall som blir gjenvunnet.

Multippel regresjonsanalyse ble også brukt for å forsøke å identifisere sammenhenger ved å inkludere andre variabler. Gjenvinningsratene påvirkes av mange faktorer så ulike variabler ble inkludert i analysen:

- inntekt fra gebyr per person
- tidsvariablen: om kommunene hadde/ikke hadde hentesystem for papp og papir i 1992 og/eller i 1995
- prosent av husholdningene som har et kildesorteringssystem for papir og papp
- befolkningstetthet
- den enkelte kommunes avstand til en større by (sentralitetsvariabel)
- prosent av det totale kommunebudsjettet som ble brukt på avfallssektoren
- totale kostnader per tonn behandlet avfall

Den eneste signifikante sammenheng som ble funnet, er mellom gjenvinningsraten og tidsvariablen (de årene den enkelte kommune hadde et hentesystem for papp og papir) og mellom gjenvinningsraten og sentralitetsvariablen. Analysene viser at tidsvariablen alene forklarer 25-28 percent av variasjonene i gjenvinningsratene. Ved å inkludere både tidsvariablen og sentralitetsvariablen viser det seg at det bare er en liten økning (27-31 percent) i forklarte variasjoner.

Hovedkonklusjonen av analysen blir dermed at gebyrnivået ikke påvirker gjenvinningsraten i særlig grad. Det er ikke funnet en identifiserbar sammenheng mellom gebyrnivå og gjenvinningsrate. Det som påvirker gjenvinningsraten er tidsvariablen.

Denne konklusjonen kan forklares ut fra en innovasjonsadopsjonsteori der tid er en viktig faktor i forståelsen av handling. Det kan se ut som gjenvinning fremdeles er i en tidlig utviklingsfase i mange kommuner, og at noen kommuner er mer oppfinnsomme enn andre i sin måte å stimulere til økt gjenvinning.

Ordliste:

Norsk	**Engelsk**
avfallsgebyrnivå	solid waste collection fee
bosettingstetthet	population density
hentesystem	curbside collection system
kildesortering	source separation
kommune	municipal
sentralitet	centrality

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1. Introduction

In 1995, 1.26 million tons of solid waste were produced by Norwegian households but only 18 percent of this was recycled (Statistics Norway 1996). Although there has been a steady increase in the amount of household solid waste collected for recycling (Statistics Norway 1997c) each person continues to produce more solid waste. Bruvoll and Ibenholt (1995) forecast that municipal waste will grow by 40 percent from 1992 to 2010. There is concern about the mountains of solid waste that are being produced each year and the government is trying to find ways to reverse this trend.

One approach that the government is considering is a charge or tax (Løvik 1997; Haakaas 1997) to try to encourage households to decrease the amount of solid waste they produce and to increase the amount of waste they send to recycling. It has been estimated that each household would pay approximately 150 kroner more per year with this new charge.

The logic behind this proposal is the belief that there is a positive relationship between the solid waste collection fee level that households pay and the amount of solid waste recycled. In other words, a higher annual household fee level would result in higher rates of recycling from households. There is skepticism towards this view if the fee is only a marginal increase over the current fee levels (Skogstrøm 1997).

There is support for this view from a number of econometrics analyses from the United States. Kinnaman and Fullerton (1994; 1997) and Fullerton and Kinnaman (1994; 1995) have focused on analyzing recycling rates and fees per unit of garbage under a number of different conditions including the option of illegal dumping. They conclude that fees do influence recycling rates but it is not a simple relationship. Repetto, *et al.*, (1992) also advocate the use of fees as a method for influencing household behavior.

Although there have been analyses in other countries, an analysis of recycling rates and fees has not been made using the Norwegian solid waste statistics. Therefore, the focus of this analysis is to investigate if a relationship exists between household solid waste collection fee levels and household recycling levels at the municipality level. The analysis technique used in this study is linear regression and the waste statistics from 1995 are the primary source of data.

The major question to be examined in this analysis is:

Are household recycling rates related to household collection fee levels?

The relationship between solid waste collection fees and recycling rates will be investigated only for households and not for industry. The main reason for focusing on households is because the waste statistics available for industry are not as complete or reliable as those for households. Also, industry uses a variety of options for treating solid waste that are outside of the scope of the 1995 municipal solid waste survey.

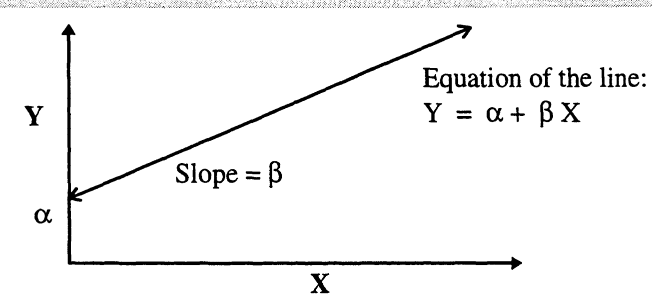
2. Definitions and Terminology

Simple linear regression and multiple linear regression are the analytical methods used in this study. A brief review of the terminology is given before going into the results.

Linear regression analyses result in a model for predicting one variable based on one or several other variables. In single regression there are only two variables, one that is to be predicted and one that is explanatory. In multiple regression there is one variable to be predicted and several explanatory variables.

The general form of a linear regression model is the formula for a line: $Y = \alpha + \beta X$
where Y is the variable to be explained or predicted, X is the explanatory variable, α (alpha) is the constant or Y-intercept, and β (beta) is the variable coefficient or slope. The following figure shows these relationships.

Figure 2.1 **Identification of regression analysis terminology**



When evaluating a regression model there are several components that need to be considered. First, there needs to be an evaluation of how close the actual data points are to the model (or line). This is evaluated by looking at the R-square and adjusted R-square values. These values give an indication of how much of the variation in the data is explained by the model. High R-square values are an indication of a good predictive model. Low R-square values mean that the data scatter is too wide to use a line as a good description of that data.

The second element that needs to be evaluated is β (beta), the coefficient of the explanatory variable. The evaluation of β is made by testing the null hypothesis that $\beta = 0$. This is done by a t-test. Two results of the t-test are given. One is a value labelled "T statistic" and the second is labelled "Probability > |T|". The results which would indicate that the estimate of the coefficient is significantly different from zero are a high T statistic value and a low Probability > |T| value (i.e., 0.0001).

The third consideration in evaluating a regression equation is to look at the signs (+ or -) of the variables to see if the relationship makes sense. If a negative relationship is expected then the sign of the coefficient should be negative.

An estimate of the Y-axis intercept, α (alpha) is part of the model but evaluating it is not of major importance in this context.

An example of how to evaluate the results is provided next. The results of the regression analysis from Section 4.2.1 are given and an explanation for evaluating and interpreting these results are described.

Regression model:
Total household waste collected for recycling = -46.50 + 0.197 x Total household waste generated

Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
0.1973	58.1297	0.0001	0.8864	0.8862

First, the r-square value and adjusted r-square values show that 88.6 percent of the variation in the household waste collected for recycling can be explained by the model. This would be considered a high value and would be thought of as an indication of a good predictive model. But before that conclusion can be made, the two other evaluations need to be made. The estimate of β (beta) is examined next. The T statistic value is very high and the Probability > $|T|$ value is very low. From these results the evaluation would be that the model is good. The final evaluation is to examine the sign of the coefficient and determine if is appears to be a logical relationship between the variables. In this case, the expected relationship between the total amount of waste collected for recycling and the total amount of household waste generated is positive. In other words, it would be expected that the more household waste produced, the more waste is collected for recycling. Therefore a positive sign for beta is expected and is in fact observed. The final conclusion regarding this regression model is that it is quite good. It has a high r-square value, a significant coefficient (beta) and the sign of the coefficient indicates a logical relationship.

Before going into the analyses, hypothesis testing needs to be briefly discussed. A null hypothesis (H_0) is developed so that the desired result is to reject the null hypothesis. Using the same example above, the null hypothesis related to that regression analysis is:

H_0 : There is no relationship between the total amount of waste collected for recycling and the total amount of household waste generated.

This null hypothesis is evaluated against the alternative hypothesis:

H_A : There is a relationship between the total amount of waste collected for recycling and the total amount of household waste generated.

Since the results of the regression model were so good, i.e. high r-square and significant coefficient (beta), then the null hypothesis (H_0) is rejected and the alternative hypothesis (H_A) is accepted.

3. Conceptual definition of research question

It is helpful to clarify the types of variables available for this analysis and to also define the research question from a conceptual perspective. Examining the information available from the national 1995 solid waste survey, two types of variables are identified. One type could be roughly considered as an indicator of personal behavior. The other type is an indicator of municipal structure and infrastructure. Classifying the variables in this way provides a better understanding of what types of variables are being used in this analysis.

The information which could be considered as being related to personal behavior is:
- amount of household solid waste collected for recycling

This is the variable that is the main focus of this analysis. The other variables will be used to try to explain the variation observed in this variable.

All of the other variables available for this analysis could be considered as indicators of municipal structure and infrastructure. These include:
- municipal income from solid waste collection fees
- most common annual solid waste collection fee paid by the average household
- municipal expenditures
- whether the municipality has a curbside collection system for newspaper and cardboard
- the percent of households that have a source separation curbside collection system for newspaper and cardboard
- the population density
- the closeness of the municipality to major cities
- percent of total municipal budget spent on solid waste sector
- the cost per ton of solid waste treated

Using this view of the variables, the main relationship to be investigated in this analysis can be understood as:

How is the behavior the household (recycling levels) related to a variety of municipal infrastructure parameters (fee levels, population density, costs, percent of budget, etc.)

The main variable to be explained is the personal behavior of the individuals in the household i.e., household recycling rates of solid waste. The two specific variables which indicate household recycling rates used in this analysis are:
1. Amount of household solid waste per person sent to recycling
   [This variable will be referred to as "amount recycled per person"]
2. The percent of the total amount of household solid waste sent to recycling to the total amount of household solid waste.
   [This variable will be referred to as "Percent recycled."]

4. Description of Data and Initial Data Exploration

Before presenting the results of the regression analyses, the data are described and briefly probed.

4.1 Description of Data

The data used for this analysis come from the 1995 national solid waste survey.[1] In addition, other descriptive statistics for the municipalities were used, including:

1. population
2. population density[2]
3. centrality
4. total municipal budget
5. whether the municipality had a curbside collection system for collecting paper in 1992.[3]

The following bar chart shows the amount of household waste generated in each county and the amounts of that waste sent for recycling. This provides a rough overall view of the generation of solid waste and recycling on a slightly wider geographic basis.

[1] See Statistics Norway 1997b, for original survey results.

[2] Measured in terms of the percentage of the population in the municipality resided in densely populated areas as of the last census, 3 November 1990 (Statistics Norway 1994a).

[3] Obtained from the 1992 national survey (Statistics Norway 1994b).

Figure 4.1 **Total amount of solid waste generated showing the amount collected for recycling. County. Tonnes. 1995**

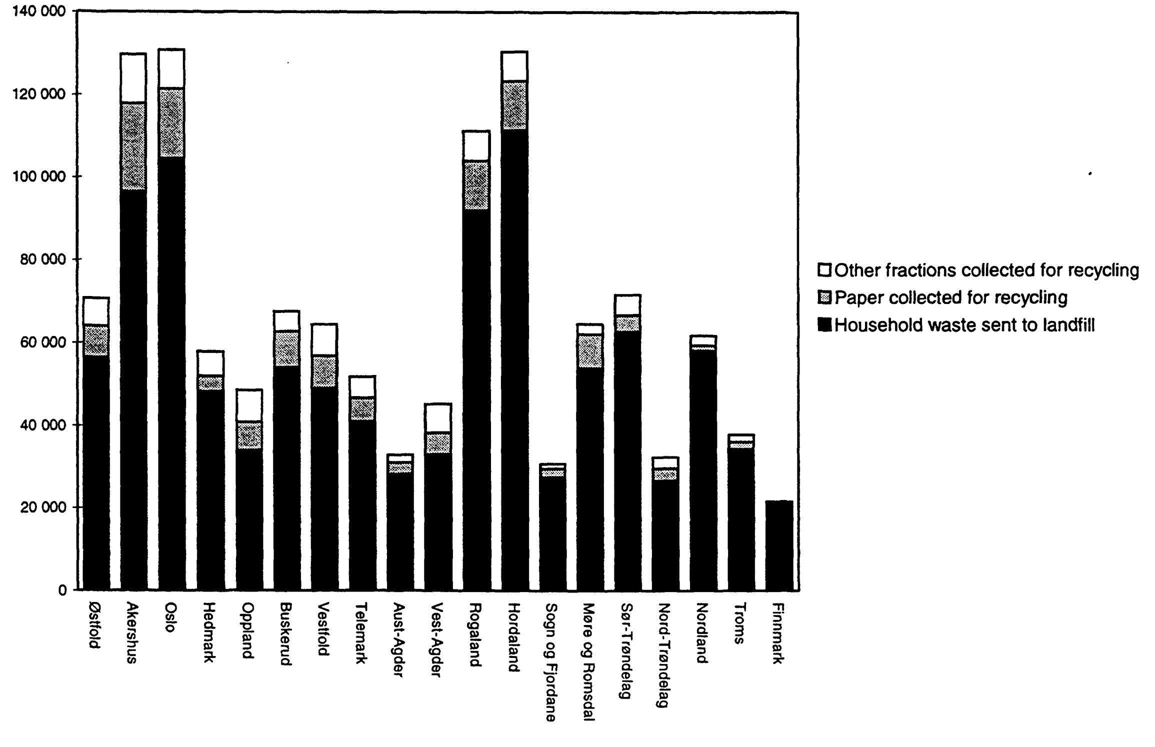
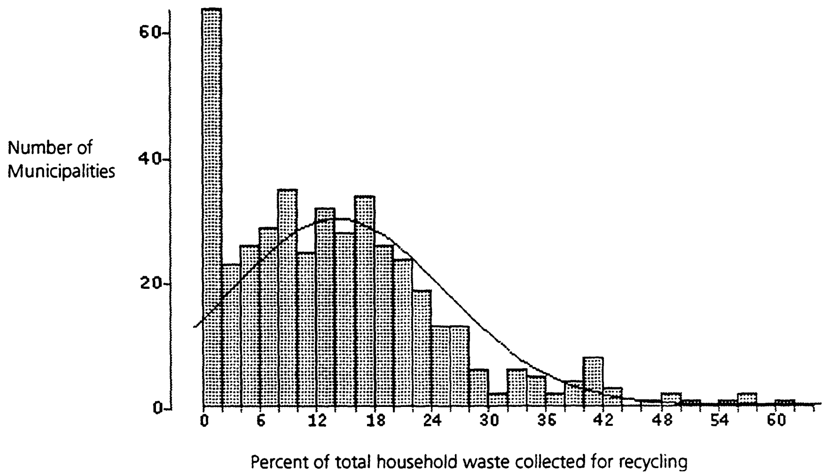


Figure 4.2 shows a histogram of the percent of recycled material from each municipality. This gives a picture of how much household waste is recycled on the municipal level. There are a large number of municipalites which do not have any type of system for recycling materials which results in a very tall first bar in the histogram. A normal curve is added to the histogram for reference.

Values associated with this distribution:

Average	14.35	percent
Standard deviation	11.5	percent
Maximum value	61.8	percent
Minimum value	0.0	percent
Number in sample	435	municipalities

Figure 4.2 **Histogram of percent of total household waste collected for recycling**



If the 47 municipalities which report zero tonnes of waste sent to recycling are removed from the sample, the values for the average and standard deviation change slightly.

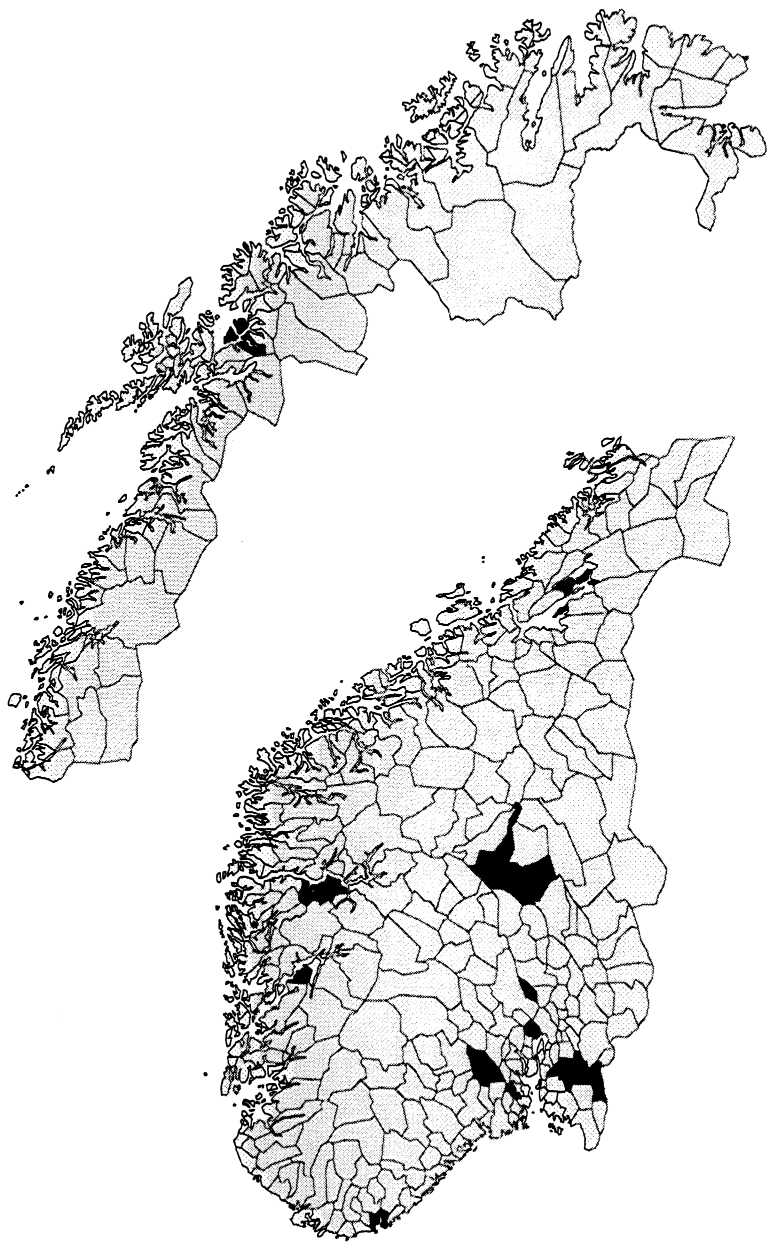
Average	16.1	percent
Standard deviation	11.0	percent
Number in sample	388	municipalities

It is interesting to note that there are 24 municipalities (5.5 percent of the total) which have a recycling rate greater than the mean plus two standard deviations (percent recycled ≥ 37 percent). These municipalities are:

	Percent waste recycled		Percent waste recycled		Percent waste recycled
1. Utsira	37.3	9. Marker	40.3	17. Jondal	46.8
2. Bærum	38.5	10. Spydeberg	40.3	18. Ibestad	49.8
3. Sør Fron	39.5	11. Askim	40.3	19. Kristiansand	49.9
4. Eidsberg	39.7	12. Hobøl	40.4	20. Gratangen	50.8
5. Jevnaker	39.8	13. Ramnes	40.5	21. Gausdal	55.7
6. Vik	40.0	14. Mosvik	42.5	22. Lillehammer	56.2
7. Skiptvet	40.3	15. Kongsberg	43.3	23. Inderøy	57.1
8. Trøgstad	40.3	16. Frosta	43.6	24. Øyer	61.8

The location of these municipalities are shown on the following map (Figure 4.3). It is interesting to note that there appears to be a number of clusters of neighboring municipalities with high recycling rates. There is a cluster of municipalities in Oppland with Lillehammer, Gausdal and Øyer. Another cluster is located in Østfold including Eidsberg, Skiptvet, Trøgstand, Marker, Spydeberg, Askim, and Hobøl. And a third cluseter is found in Nord-Trøndelag with Mosvik, Frosta, and Inderøy. This type of geographic clustering can be a result of inter-municipal cooperation regarding recycling. An analysis of the organization of waste recycling in these municipalities is, however, not the focus of this report.

Figure 4.3 Map of Norway showing the 24 municipalities with the highest recycling rates



Digitale kartdata: Statens kartverk

4.2 Characteristics of the Data

There are a number of characteristics of the data that need to be investigated and solutions for a number of problems need to be found before analyses can be attempted.

Data collected on the municipality level in Norway have very wide ranges. Some of the 435 municipalities are very small with fewer than 500 inhabitants and others include the major metropolitan areas. This produces a data set with a few very large outlier values and a large cluster of small values. Since the outliers strongly define the regression and correlation analyses, the regression analysis results are largely influenced by only a couple of data points. An example of this problem is provided below.

4.2.1 Relationship between total household waste collected for recycling and the total amount of household waste generated

Regression model:
Total household waste collected for recycling = - 46.50 + 0.197 x Total household waste generated

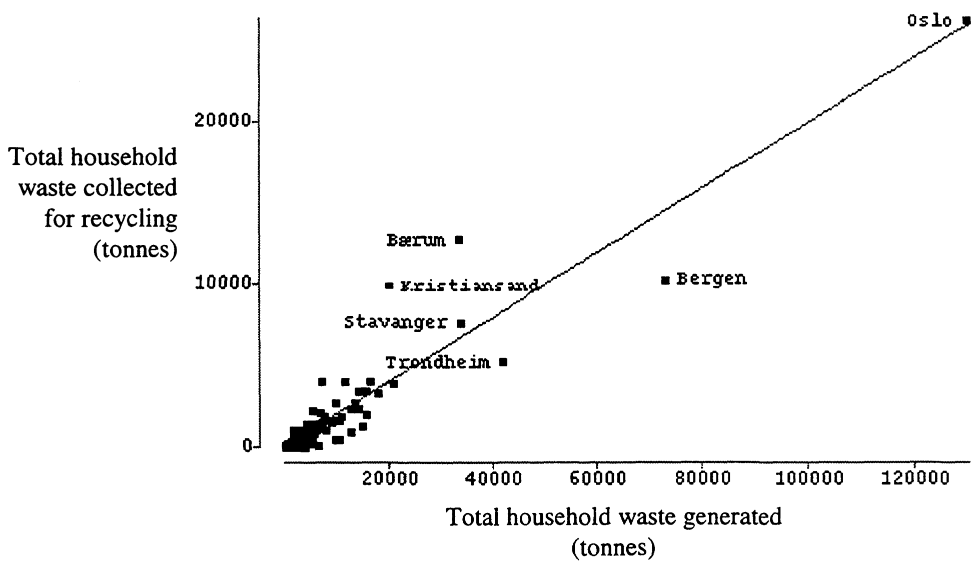
Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
0.1973	58.1297	0.0001	0.8864	0.8862

If the six municipalities labelled in Figure 4.4 are excluded from the analysis the cluster of data at the bottom of the graph is expanded. This shows a wider data scatter than is seen in Figure 4.4. This increased scatter is reflected in the regression results by the lower r-square value, 77 percent vs. 88.6 percent. But the coefficient (beta) is very similar, 0.1942 vs. 0.1973, and is significant (low probability, 0.0001) in both cases. So the results are roughly the same in both cases. But the problem still remains that the highly populated areas tend to determine the results.

Regression model:
Total household waste collected for recycling = - 56.67 + 0.194 x Total household waste generated

Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
0.1942	38.1681	0.0001	0.7733	0.7728

Figure 4.4 **Total household waste collected for recycling vs. total amount of household waste generated**



Regression models can be used to evaluate performance in relation to the average. The regression model provides an expected average and can be used to evaluate the performance of the municipalities. For example, using the first equation (also shown in Figure 4.4), the performance of Bærum and Kristiansand can be seen as higher than the average and that the performance of Trondheim and Bergen can be seen as below the average (the regression line). Exactly how much above or below the average can be evaluated using the regression equation. Using the equation, the predicted amounts can be calculated and then compared with the actual amounts. The equation predicts an average recycling rate of 19.3 percent (i.e., the value of β). Bærum and Kristiansand are definitely above this level and Bergen and Trondheim are below.

Municipality	Total household waste generated	Predicted amount of waste recycled	Actual amount of waste recycled	Actual percent recycled
Bergen	73 243	14 382	10 414	14.2%
Trondheim	42 153	8 304	5 351	12.7%
Bærum	33 591	6 617	12 947	38.5%
Kristiansand	20 151	3 970	10 062	49.9%

The conclusion from this analysis is that regression analyses can provide interesting insights into the data but the large values are very influential and some way of dealing with the outliers needs to be found before additional analyses can be made.

4.2.2 Dealing with the problem caused by the wide range of values

One way of dealing with outliers is to exclude them from the analysis. If this approach is used in this analysis, the result would be that major parts of the Norwegian population will be eliminated from the analysis. This defeats the purpose of the analysis. Another approach is to transform the original variables in a way that the population size of the municipality is not the distinguishing factor in the analysis. This will be the approach used in this analysis. This will be accomplished by dividing the municipal values by the population to give values *per person.* The other approach used will be to calculate the municipal value as a percent.

4.3 Testing two relationships

To check that using amounts *per person* is appropriate in this analysis, two relationships which are expected to be strong will be explored before further analyses of the fee levels and recycling amounts are analyzed.

The two relationships that are expected to be strong:

1. Municipal income from fees *per person* and municipal expenditures *per person*
2. Amount of household solid waste collected for recycling *per person* and amount of household solid waste *per person.*

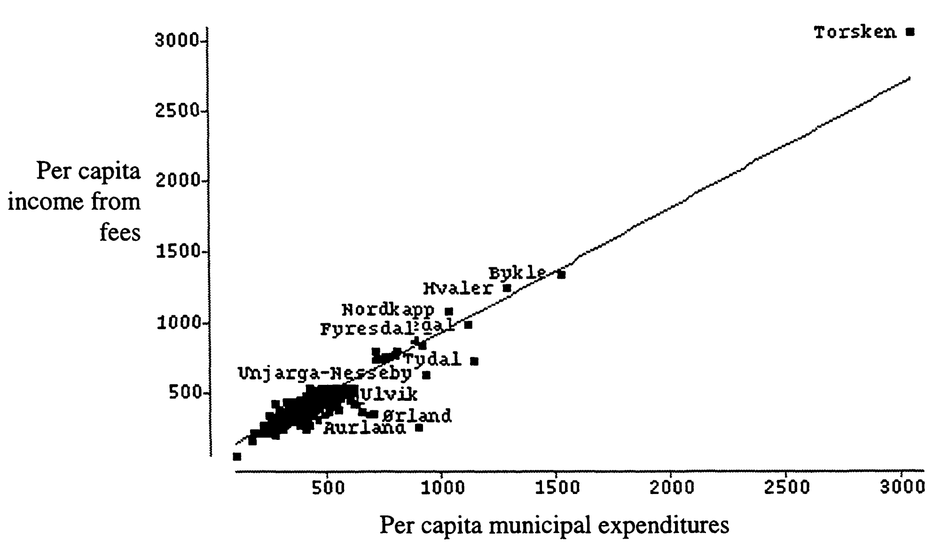
4.3.1 Municipal Income from fees vs. municipal expenditures[4]

One relationship that is expected to be strong is between income from fees *per person* and total expenditures *per person.* This relationship should be strong because there is a regulation from the Mininstry of the Environment which states that the municipality does not have the right to collect more income from fees than is needed to cover the expenditures of the solid waste sector. To test this relationship, the following hypothesis is developed:

H_0: There is no relationship between income from fees per person in the municipalities and expenditures in the municipalities per person

The scatter diagram and regression results are given below.

Figure 4.5 **Income from fees per person vs. municipal expenditures per person**



Regression equation:
Income from fees per person = 36.46 + 0.905 x Municipal expenditures per person

Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
0.9045	47.2489	0.0001	0.8376	0.8372

[4] Municipal expenditures include overhead and running costs plus investment capital costs.

Torsken appears to be quite an outlier and should perhaps be excluded from this calculation. This was checked by removing Torsken from the analysis. Again, the r-square value decreases but the overall regression equation is only slightly changed. The variable coefficient is significant at the 5 percent confidence level in both regression analyses.

Regression equation:
Income from fees per person = 89.15 + 0.783 x Municipal expenditures per person

Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
0.7828	39.7159	0.0001	0.7850	0.7845

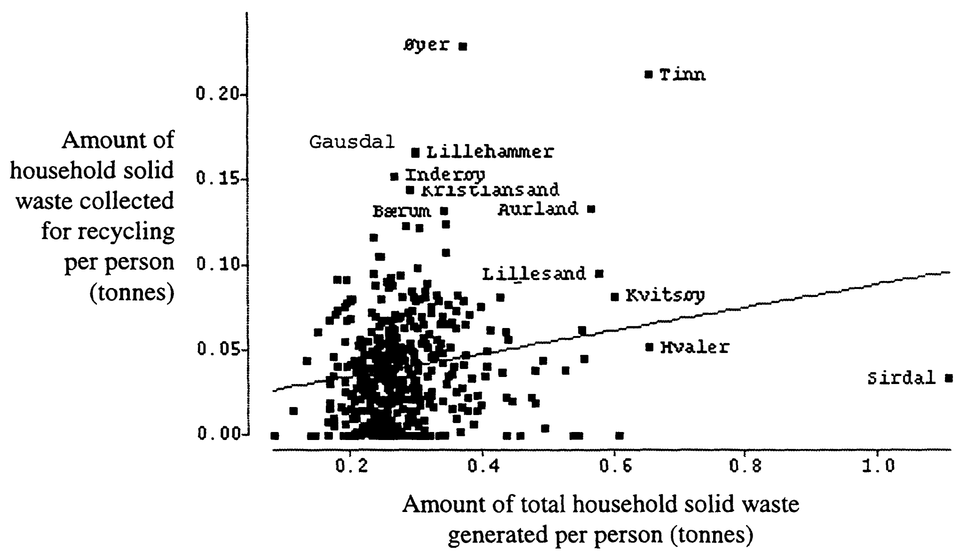
The regression results lead to the rejection of the null hypothesis that there is no relationship between income per person and expenditures per person. Therefore, the alternative hypothesis that there is a relationship between these variables must be accepted. The regression equations can be interpreted as estimates of this relationship.

4.3.2 Amount of household solid waste per person to recycling vs. amount of household solid waste per person

It is expected that the more per capita household waste that is produced, the more waste will be sent to recycling. To test this relationship, the following hypothesis is developed:

H_0: Per capita amount of household waste sent to be recycled is not related to amount household waste per person.

Figure 4.6 **Amount of household solid waste collected for recycling per person vs. amount of total household solid waste generated per person**



Regression Model:
Total amount of household solid waste sent to recycling per person = 0.0205 + 0.0670 x Total amount of household solid waste generated per person

Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
0.0670	3.8642	0.0001	0.0333	0.0311

In this case, the regression results are not providing a clear picture whether to reject the null hypothesis or not. The adjusted r-square value is very low which would indicate that this is not a good model, but the coefficient of the variable is significant. In this case, the null hypothesis is still rejected because there is a significant relationship between the two variable (indicated by the significance of the coefficient). But using the regression model for prediction purposes is not valid since the the r-square value is so low. The model explains very little of the variation of the recycling rate variable which would be an indication that there are other factors which are playing an important role.

4.3.3 Conclusions

The initial data analyses do indicate that there are some statistically significant relationships between the variables. The expected relationships were tested and found to be significant therefore using these per person values is an appropriate approach for additional analysis. In the next section, the relationship between fee levels and recycling rates will be investigated.

5. Investigating the relationship between municipal recycling rates and solid waste collection fee levels

The major focus of this solid waste analysis is on the relationship between the amount of solid waste collected for recycling from households and the solid waste fee levels. The same problem regarding the size of the municipalities exists for the variables which relate to these relationships. Again this problem will be handled by calculating per person values and percent of total waste collected for recycling.

The dependent variable (y-axis) is the amount of household solid waste collected for recycling. This has two possible definitions:
1. amount of household solid waste per person collected for recycling
   [This variable will be referred to as "Amount recycled per person"]
2. percent of total household waste collected for recycling
   [This variable will be referred to as "Percent recycled."]

The independent variable (x-axis) is the solid waste collection fee levels. This also has two possible definitions:
1. the typical household annual solid waste collection fee, and
2. municipal income from fees per person.

Each of these relationships was initially explored using bivariate regression analyses and scatter diagrams. Then additional variables are introduced to try to develop a more complete model for the recycling rate variables.

5.1 Household recycling rates: bivariate analyses

5.1.1 Analyses including all 435 municipalities

The bivariate regression results for amount recycled per person vs. each of the two fee variables and the results for the percent recycled vs. each of the two fee variables are given below. The analysis uses the entire data set of 435 municipalities.

Amount recycled per person vs.

	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
• typical household annual solid waste collection fee	-1.5×10^{-6}	-0.2106	0.8333	0.0001	0
• income from fees per person	4.1×10^{-6}	0.5047	0.6140	0.0006	0

Percent of household waste collected for recycling vs.

	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
• typical household annual solid waste collection fee	0.0026	1.0437	0.2972	0.0025	0.0002
• income from fees per person	-0.0005	-0.1580	0.8746	5.8×10^{-5}	0

From these results it can be concluded that no relationship exists.

To try to identify some relationships between the two variables (recycling rates and fees), the larger data set is reduced to municipalities that have more similar geographic and population densities. The first selection includes all municipalities in Norway with a population density[5] greater than 60 percent. The second selection of 113 municipalities are located in *southern* Norway with population densities greater than 60 percent.

[5] Population density is measured in terms of the percentage of the population that in the municiplaity concerned resided in densely populated areas on the date of the census 3 November 1990 (Statistics Norway 1994a).

5.2.1 All Norwegian municipalities with a population density rating of 60 percent or greater

There are 144 municipalities with a population density rating of 60 percent or greater. It was thought that the more densely populated municipalities in Norway would have more similar recycling rates. These 144 municipalities were used for the following analyses.

Amount recycled per person vs.

	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
• typical household annual solid waste collection fee	-2.3×10^{-5}	-1.7639	0.0799	0.0214	0.0146
• income from fees per person	-4.6×10^{-5}	-2.3872	0.0183	0.0386	0.0318

Percent of household waste collected for recycling vs.

	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
• typical household annual solid waste collection fee	-0.0074	-1.6057	0.1106	0.0178	0.0109
• income from fees per person	- 0.0211	-3.1968	0.0017	0.0671	0.0606

From these analyses it does not appear to be any significant relationship between these two parameters in this portion of the data.

5.1.3 Southern Norwegian municipalities with with a population density rating of 60 percent or greater

If the three northern counties, Nordland, Troms and Finnmark, are excluded because they have markedly different characteristics with regards to the long distances and transportation challenges than in southern Norway and the amount of waste collected for recycling is low and if only the municipalities which have a population density defined as above 60 percent in the remaining southern part of Norway are included in the analysis, perhaps some relationships can be identified. It was reasoned that the municipalities which are more densely populated in the southern part of Norway would have more similar characteristics and behaviors. There are 113 municipalities which have these characteristics.

Amount recycled per person vs.

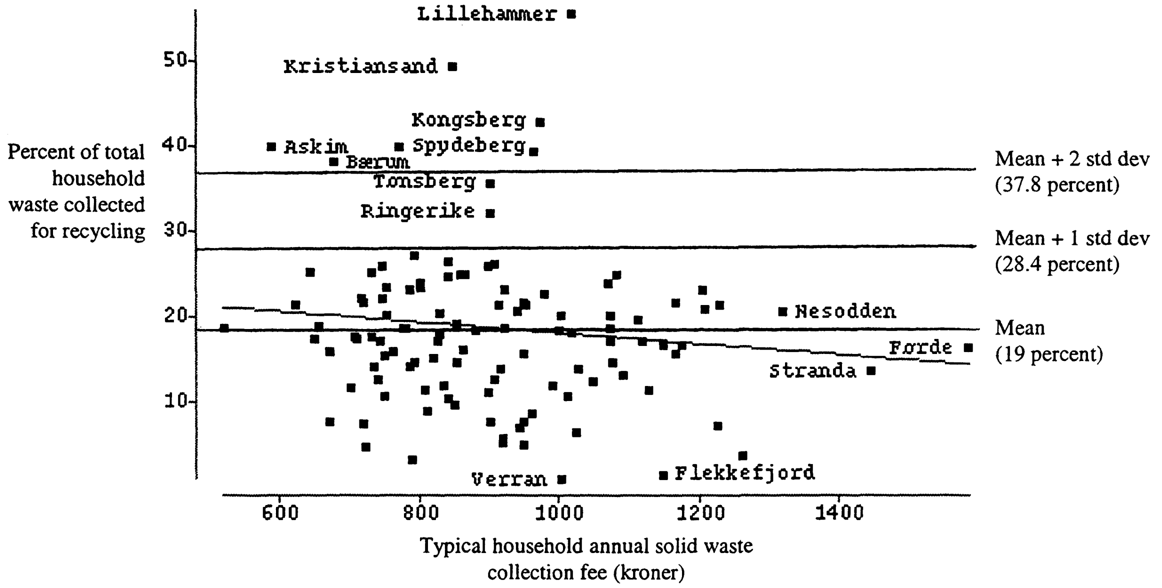
	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
• typical household annual solid waste collection fee	-2.2×10^{-5}	-1.5729	0.1186	0.0218	0.0130
• income from fees per person	-3.5×10^{-5}	-1.6166	0.1088	0.0230	0.0142

Percent of household waste collected for recycling vs.

	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
• typical household annual solid waste collection fee	- 0.0063	-1.3059	0.1943	0.0151	0.0063
• income from fees per person	- 0.0167	-2.2313	0.0277	0.0429	0.0343

These analyses also did not show any strong bivariate relationships between the recycling rate variables and the fee level variables. The only major main difference observed between the 113 southern more densely populated municipalities and the 144 municipalities is that there are no municipalities with zero tonnes of recycling in the southern Norwegian municipalities.

Figure 5.1 **Percent of total household solid waste collected for recycling vs. income from fees per person in the 113 more densely populated municipalities in southern Norway**



From the scatter diagram in Figure 5.1 there appears to be a small group of municipalities which are well above most of the others. Three reference lines (mean, mean plus one standard deviation, mean plus two standard deviations) were added to the scatter diagram to help identify the different groups. The municipalities which have recycling rates greater than the mean plus two standard deviaions are: Lillehammer, Bærum, Askim, Spydeberg, Kristiansand, Kongsberg, and Jevnaker. Tønsberg and Ringerike are in the next lower group. A number of these municipalities have been previously noted for their recycling infrastructure and efforts (see Statistics Norway 1995a: Kristiansand; Statistics Norway 1995b: Bærum) and the 1994 Olympic Games could have had an effect on the recycling levels in Lillehammer since the survey was made the year after the Games were held.

The conclusion that can be made after all of these analyses is that no significant bivariate (two variable) relationships have been identified between recycling rates and fee levels. This is the case using three different groupings of the data. Although no significant bivariate relationship exists, it is possible that other factors may be influencing household recycling rates. This will be investigated in the next section using multiple regression.

5.2 Multiple regression exploration of household recycling rates

It does not appear that fee levels is having a major impact on recycling rates and from the two groups of data observed in the scatter diagram (Figure 5.1), it is possible that the infrastructure of the municipality is having a greater effect on household recycling rates than fee levels. To be able to explore this possibility a set of dummy variables was developed.

The dummy variables[6] (D1 and D2) were developed from the variables in the solid waste statistics from the 1992 national survey and the 1995 national survey data which indicate if the municipality had a curbside collection system for collecting paper and cardboard in 1992 and/or in 1995. Having a system for collecting recyclable materials that makes it as easy as possible for the household to deliver material to be recycled was considered to be the best indicator of the municipality's recycling infrastructure available for this analysis.

[6] The dummy variable were defined in the following way:
D1=0 and D2=0: No curb recycling in 1992 and no curb recycling in 1995
D1=0 and D2=1: No curb recycling in 1992 and curb recycling in 1995
D1=1 and D2=1: Curb recycling in both 1992 and 1995
This variable does not include centralized locations where paper and other materials (glass, batteries, etc.) can be brought for recycling. The variable is only defining a curbside collection system. Five municipalities were not able to be coded in this fashion and were excluded from the analysis (Vang, Øystre Slidre, Nord-Aurdal, Sør-Aurdal and Etnedal).

In addition, a number of other variables were included in the multiple regression analysis which cover other parameters. Both recycling rate variables were examined.

5.2.1 Amount recycled per person – multiple regression analysis

The following hypothesis was developed and tested using multiple linear regression.

H_0: The amount of solid waste collected for recycling per person is not related to:

- income from fees per person
- whether the municipality has a source separation curbside collection system for newspaper and cardboard (defined as D1 and D2)
- the percent of households that have a source separation collection system for newspaper and cardboard
- the population density
- the closeness of the municipality to major cities[7]
- percent of total municipal budget[8] spent on solid waste sector
- the cost per ton of solid waste treated

Amount recycled per person vs.

	Beta	T statistic	Probability >ITI	R^2	Adjusted R^2
Multivariate equation				0.2819	0.2682
• income from fees per person	2.291×10^{-6}	0.1569	0.8754		
• whether the municipality has a source separation curbside collection system for newspaper and cardboard					
• D1	0.0089	2.2287	0.0264		
• D2	0.0203	2.7623	0.0060		
• the percent of households that have a source separation collection system for newspaper and cardboard	0.0043	0.5944	0.5526		
• the population density	-0.0005	-0.9399	0.3478		
• the closeness of the municipality to major cities	0.0038	2.9403	0.0035		
• percent of total municipal budget spent on solid waste sector	0.0057	1.4328	0.1527		
• the cost per ton of solid waste treated	-4.012×10^{-6}	-1.3730	0.1705		

The results of this analysis indicate that 28 percent of the variation in the recycling rate data is explained. This is not a very large amount. However, there are some variables with significant coefficients therefore, the null hypothesis is rejected and the alternative hypothesis accepted. Or more specifically that there does appear to be a potentially significant relationship between the recycling rate and the time when the municipality had a curbside collection system, and the recycling rate and the closeness of the municpality to a major city (centrality). A new hypothesis is developed for testing the relationship between the recycling rate and the time of implementing a curbside collection and the closeness of the municipality to major cities

The following hypothesis has fewer variables than the previous one and includes only those variables which appeared to have a strong relationship to the recycling rate variable.

H_0: The amount of solid waste collected for recycling per person is not related to:

- whether the municipality has a source separation curbside collection system for newspaper and cardboard (as defined by D1 and D2)
- the closeness of the municipality to major cities (centrality)

[7] Closeness of the municipality to major cities was defined by centrality. To reduce the number of categories, four categories were defined from the seven centrality designations (Statistics Norway 1994a): 0 = 0A and 0B, 1 = 1A and 1B, 2 = 2A and 2B, 3 = 3.

[8] The percent of the municipal budget spent on solid waste treatment was calculated using the total costs reported from the 1995 solid waste survey and the total municipal budget (Table 12 in Statistics Norway 1997a).

Amount recycled per person vs.

	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
Multivariate equation				0.2728	0.2676
• whether the municipality has a curbside collection system for newspaper and cardboard					
• D1	0.0086	2.2178	0.0271		
• D2	0.0248	7.1594	0.0001		
• the closeness of the municipality to major cities	0.0039	3.4119	0.0007		

Regression equation:

Amount recycled per person = 0.0184 + (0.0086 x D1) + (0.0248 x D2) Curbside collection system + 0.0039 x Closeness of the municipality to major cities

These regression results indicate that 27 percent of the variation in the recycling rate variable, the amount of solid waste collected for recycling per person, is explained by the model. This is not a very high value but two of the variable coefficients are statistically significant at the 10 percent level. Therefore, the null hypothesis is rejected and it is concluded that there is a statistically significant relationship between these variables. Although, again, the model cannot be used with much confidence for predicting the recycling rate.

5.2.2 Percent of total household waste that is collected for recycling -- multiple regression analysis

The same multivariate regression analyses were made for the other recycling rate variable, the percent of total household waste that is collected for recycling.

H_0: The percent of total household waste that is collected for recycling is not related to:

- income from fees per person
- whether the municipality has a source separation curbside collection system for newspaper and cardboard (as defined by D1 and D2)
- the percent of households that have a source separation collection system for newspaper and cardboard
- the population density
- the closeness of the municipality to major cities
- percent of total municipal budget spent on solid waste sector
- the cost per ton of solid waste treated

Percent of total household waste that is collected for recycling vs.

	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
Multivariate equation				0.3263	0.3134
• income from fees per person	-0.0054	-1.0827	0.2796		
• whether the municipality has a source separation curbside collection system for newspaper and cardboard					
• D1	3.4502	2.5461	0.0112		
• D2	7.7613	3.0904	0.0021		
• the percent of households that have a source separation collection system for newspaper and cardboard	1.5655	0.6329	0.5271		
• the population density	- 0.2079	-1.0716	0.2845		
• the closeness of the municipality to major cities	1.8069	4.0572	0.0001		
• percent of total municipal budget spent on solid waste sector	0.6825	0.5048	0.6140		
• the cost per ton of solid waste treated	0.0021	2.1495	0.0322		

The results of this analysis indicate that only 31-33 percent of the variation in the data is explained and the null hypothesis is again rejected because it does appear that there could be a significant relationship between the percent of total household waste collected for recycling and the time when the municipality had a curbside collection system and the closeness of the municpality to a major city (low probability > |T| values).

The following hypothesis was developed and tested using multiple linear regression.

H_0: The percent of total household waste that is collected for recycling is not related to:
- whether the municipality has a source separation curbside collection system for newspaper and cardboard (defined as D1 and D2)
- the closeness of the municipality to major cities (centrality)

Percent of total household waste that is collected for recycling vs.

	Beta	T statistic	Probability > ITI	R^2	Adjusted R^2
Multivariate equation				0.3118	0.3069
• whether the municipality has a curbside collection system for newspaper and cardboard					
• D1	2.5986	1.9550	0.0512		
• D2	9.6520	8.1233	0.0001		
• the closeness of the municipality to major cities	1.6186	4.0903	0.0001		

Regression equation:

Percent of total household waste that is collected for recycling = 6.2814 + (2.5986 x D1) + (9.6520 x D2) Curbside collection system + 1.6186 x Closeness of the municipality to major cities

This equation explains 31 percent of the variation of the percent of total household waste collected for recycling. From these results the null hypothesis is rejected, and it is concluded that there is a statistically significant relationship between the percent of household waste that is collected for recycling and whether there is a curbside collection system and the closeness of the municipality to major cities.

5.3 Recycling rates only as a function of time

If the regression analysis is performed for the recycling rate variables and only the curbside collection system variables (D1 and D2), 25 and 28 percent of the variation in the recycling rate variables is explained. These results would indicate that the curbside collection of recyclable materials is the predominant factor in explaining the recycling rates of households.

	Beta	T statistic	Probability >ITI	R^2	Adjusted R^2
Amount recycled per person vs.					
Multivariate equation				0.2528	0.2493
• D1	0.0123	3.2527	0.0012		
• D2	0.0248	7.0726	0.0001		
Percent of household waste collected for recycling vs.					
Multivariate equation				0.2847	0.2814
• D1	4.1064	3.1576	0.0017		
• D2	9.6534	7.9785	0.0001		

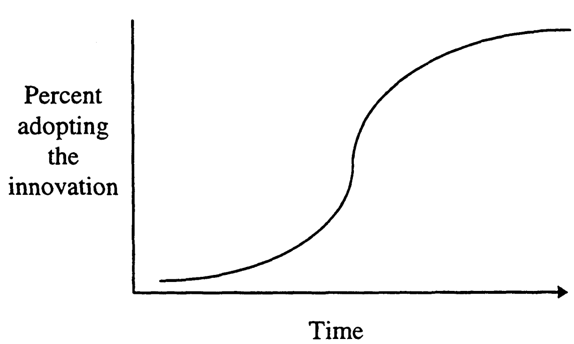
From this analysis it is also possible to conclude that the longer the municipality has a curb recycling system, the more material is collected for recycling. However, with only two points of time to include in this analysis, no description of the adaption pattern over time can be made. If a longer time series was available, it would be possible to study the adoption pattern and see how long it takes for households to increase their recycling rates and at what level the recycling rate stablizes.

6. Placing this analysis into a theoretical context

Adoption of innovation theory (Rogers 1995) would predict that a technical innovation such as a system for the collection of materials for recycling would follow an "S" shaped adoption curve. In the beginning only a few municipalites would have a collection system. As time goes on, more and more municipalities would implement this type of system. How quickly the innovation is adopted defines if the "S" curve is steep or gradual.

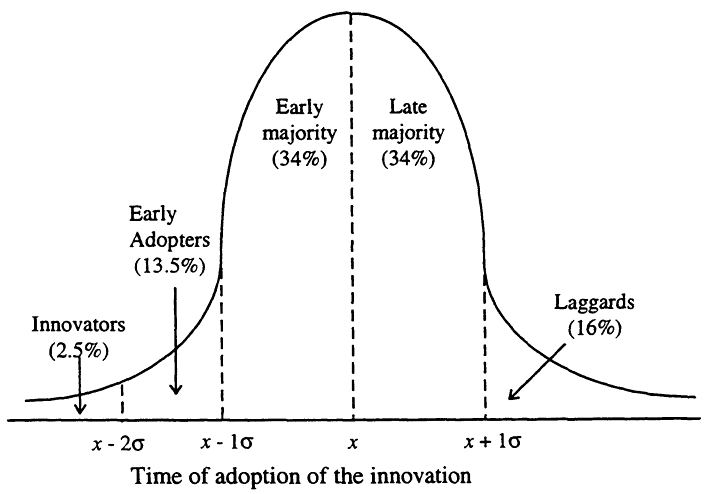
This same "S" curve adoption pattern is also useful for understanding the household recycling rate behavior. If the municipality does have a curbside collection system, not all households will participate in the scheme immediately and it will take time before people start to participate. Again as more and more households change their behavior and participate in the recycling scheme an "S" type curve of adoption behavior develops.

Figure 6.1 **"S" shaped innovation adoption curve**



Related to the "S" shaped adoption curve is a bell-shaped curve which would show which people (or municipalities) are changing their behavior quickly and which ones are not. The innovators are the first ones to try something new, followed by the early adopters. These two groups change their behavior quickly and are often considered trend setters. They are also the ones which develop and make the initial improvements of the innovation. The next group to adopt is the early majority, followed by the late majority and finally the laggards. Although the adoption pattern of an innovation does not necessarily follow an "S" shaped curve, these curves are often used as a best estimate of the expected adoption pattern over time.

Figure 6.2 **Innovation Adoption Groups (based on Rogers 1995: 262)**



From this analysis of the municipal solid waste recycling rates, it does appear that some of the municipalities are showing markedly higher household recycling rates than other municipalities. In particular, the 24 municipalities identified in section 4.1 have rates that are 2 standard deviations or more above the mean. Part of this group is also seen in Figure 5.1 as the smaller group of municipalities which are above the majority of the data scatter. According to the adopter categories defined by Rogers (1995), these municipalities could be considered as the "innovators" and "early adopters" of recycling systems in Norway.

7. Conclusion

This analysis indicates that there is no relationship between the current level of solid waste collection fees levied by the municipalities and the amount of material collected for recycling from households. Relationships between these two types of variables have been probed extensively with different portions of the data and with the inclusion of different variables in multiple regression analyses.

The only variables which were found to be significantly related to the recycling rates of households were related to the length of time that a system for curbside collection of paper had been operating in the municipality and the closeness of that municipality to major cities. The length of time that a municipality has a system for curbside collection of recyclable materials is the strongest explanatory variables for recycling rates in the municipalities. But these regression models only explain between 25 and 31 percent of the variation in the recycling rate data. So although there is a significant relationship between the variables the models are not adequate explainations of the recycling rates. There are other factors which were not able to be identified that are influencing the recycling rate variables.

The results of this study point to factors such as the inter-municipal organization of the recycling system and personal behavior that changes over time as the most influential in influencing recycling rates. In addition to these conclusions, the study by Ramm (1997) into environment related consumer behavior in Norway also points towards the behavioral component of recycling. These factors are much more subjective.

Implications of this research

The results of this study point to other factors which have more influence on recycling rates than the household collection fee levels. Factors such as geography, inter-municipal cooperation in the collection of recyclable materials, and household attitudes towards the environment would need to be considered before a more complete understanding of the household behavior is developed.

Another implication of the research results is that time plays an important role so looking at household recycling rates over time could be interesting and certain trends could potentially be identified. This type of study is currently not possible since there are only data available for 1992 and 1995, but when a longer time series of data become available this could be an interesting analysis.

Finally, the results of this study point to the innovative behavior of 24 municipalities. The recycling rates of these municipalities are markedly different from the majority of the other municipalities. It would be interesting to investigate the municipal infrastructure characteristics of the 24 innovative municipalities and to learn how they are approaching the challenge of household waste recycling. Learning how these municipalities have achieved such good recycling rates could serve as models for how the other municipalities could organize and implement successful recycling programs.

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