Household recycling of different materials in Norwegian municipalities

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Abstract:

This paper provides a material-specific empirical analysis of the determinants of household recycling behavior. The empirical model is based on a two-constraint theoretical framework that suggests that the marginal money value of time, or the opportunity cost of time, plays an important role in the household's decisions. Our regression results indicate that the opportunity cost of time is a significant determinant for recycling of several of the materials. Furthermore, our results solidify previous findings that solid waste policies, such as implementation of waste disposal fees and convenient recycling programs, are important and affect recycling of different materials to various degrees. Finally, our analysis lends support to the idea that household behavior is also motivated by many factors generally not considered by economists.

Keywords: Solid waste, recycling, unit pricing, economic incentives, intrinsic motivations, two-constraint models, opportunity cost of time

JEL classification code: Q21, Q28, H31, H41

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1. INTRODUCTION

A substantial body of economics literature has sought to explain household recycling behavior. The common conceptual approach is to think of recycling as one of several ways the household can manage waste materials from household production and consumption, see for example Kinnaman and Fullerton (1999), Jakus et al. (1996), Fullerton and Kinnaman (1995) and Morris and Holthausen (1994). Recycling is conceptualized as a type of activity that households commit to when it is sufficiently convenient and in the presence of proper economic incentives. Primary empirical attention has been given to the role of solid waste management policies, particularly the impact of waste disposal fees and publicly provided recycling programs. Much of the research was motivated by a desire to understand the effects of policies that proceeded the so-called landfill crisis in the United States, see Kinnaman and Fullerton (1999) for an overview.

Our paper adds to the existing body of literature by analyzing the impact of similar policies on household recycling behavior in Norway. Our analysis is based on a national household survey, which collected information on recycling of six separate materials: carton, paper, plastics, metals, glass, and food waste, Statistics Norway (1999). This allows us to differentiate the effects of various policy initiatives on the recycling of different materials. To our knowledge, the only other study as comprehensive as ours is Jenkins et al. (2003).[i]

One of our major finding is that both differentiated disposal fees and convenient recycling programs, such as curbside recycling and local drop-off centers, positively affect recycling levels. This differs from Jenkins et al. (2003) who fail to find that a

disposal fee has a statistically significant impact on recycling in the United States. However, they find generally stronger effects of drop-off and curbside recycling programs than what we do for Norway.

An important contribution of our paper is that we incorporate the potentially central aspect of time into the analysis. Interestingly, while most existing work is based on the conceptualization of recycling as a household production activity, few studies have explicitly recognized the role of time in the household's recycling decisions.[ii] It is generally true that participating in recycling programs is free of charge and therefore does not involve a money price. However, if recycling requires a non-trivial time effort, and households have binding time constraints, then there *is* a relevant own-price of recycling, which should be considered. For this reason, we base our analysis on a two-constraint theoretical framework, in which the household makes choices subject to both limited money and limited time. The model implies that *full prices* and *full income* should be included in the estimation of demands for recycling activities. Full prices account for both money prices and time prices while full income consists of money income and the value of the time budget. Time prices and the time budget are converted into monetary terms by the marginal money value of time (the opportunity cost of time).[iii]

Our estimation results support the idea that time plays an important role in the household recycling decision. Broadly, we find that introducing this aspect into the empirical specification improves statistical efficiency. Moreover, the marginal money value of time is found to negatively affect recycling of three materials.

A second important contribution of our paper is that we investigate several so-called non-economic factors or intrinsic motivations. In contrast to economists, who

generally ignore such aspects of behavior, researchers within sociology and psychology have established that these factors play important roles in recycling behavior, see Hornik et al. (1995), Gamba and Oskamp (1994), Oskamp (1991), Hopper and Nielsen (1991), Vinning and Ebreo (1990), and De Young (1986, 1988).

Specifically, we incorporate the idea that recycling can be considered a public good. Recycling leads broadly to less waste sitting in landfills. A landfill is generally considered a public bad. Recycling is also a form of environmental conservation. In addition to saving scarce natural resources, secondary-material production generally pollutes less than virgin material extraction and processing. *For these reasons, households could perceive their recycling efforts as a way to contribute to a public good.*

Contrary to the prediction of the standard economic model of voluntary public good contributions, several recent advances in economic theory have demonstrated that voluntary contributions can be substantial. This outcome is consistent with empirical observations on many types of human behavior (e.g. charitable giving). Non-trivial voluntary public good contributions can be rational within a neoclassical framework when there are private complementary benefits associated with these contributions. For example, Andreoni (1990) proposes a theory of warm-glow giving and Brekke et al. (2003) present an economic model of moral motivation. Both these models have this feature. Contributions could also be explained from social norm models and identity models. If the consumer or household faces potential rewards (social approval) from recycling, or similarly, punishment (social scorn) from not recycling, then contribution is more likely. Nyborg and Rege (2003) study the role of social norms in achieving *considerate smoking*. Related, if the consumer seeks identity or status as a so-called

green consumer then he or she is more likely to engage in recycling. Akerlof and Kranton (2000) use an economic identity model to explain many types of behavior.

In this paper we incorporate this aspect of recycling by simply conceptualizing public good-related complementary benefits from recycling as utility shifters in the utility function. Empirically, we test for the importance of these factors through a series of motivational questions that were included in the survey.[iv] These variables were jointly significant in all regressions as well as individually significant in many cases. We believe that this lends support to the idea that household behavior is motivated by many factors, often overlooked by empirical economists, including a desire to contribute to a public good.

Our paper proceeds as follows. Section 2 presents the canonical two-constraint behavioral model, which has important implications for the empirical specification. Next, we briefly discuss our data. Section 4 adopts an econometric approach to estimating recycling demands, given the type of data we have available. Section 5 presents the regression results and briefly discusses the broad findings for the variables of particular interest. The final section summarizes and offers some caveats, and suggestions for further research.

2. THEORETICAL FRAMEWORK

In this section, we present a behavioral model of household recycling in which recycling is treated as one of several types of household activities.

Formally, the household's choices are motivated from a general two-constraint utility maximization model. Let **x** be a vector of *N* household activities with associated

money prices **p** and time prices **t**. The household can recycle *J* different materials, which we denote by the vector **r**. Recycling is a subset of all the possible household activities, hence $\mathbf{r} \subset \mathbf{x}$ and $J < N$. The corresponding money and time prices of recycling are $\mathbf{p_r}$ and $\mathbf{t_r}$ respectively, where $\mathbf{p_r} \subset \mathbf{p}$ and $\mathbf{t_r} \subset \mathbf{t}$.[v] The household chooses activity levels subject to strictly binding money budget $M = \mathbf{px}$ and time budget $T = \mathbf{tx}$.[vi] Both budgets are assumed to be the exogenously determined via a dynamically efficient labor market participation choice.

Utility is a function of activity levels **x** and a vector of exogenous utility shifters **s**. Thus, we can write the direct utility function $u = u(\mathbf{x},\mathbf{s})$, which we maintain takes on all the usual properties of a well-behaved utility function. The utility shifters consist of variables describing the household, such as socioeconomic characteristics. The utility shifters could also include subjective quality attributes, or perceived complementary benefits, potentially associated with some activities. This subset of utility shifters will be denoted by **q**.[vii]

The indirect utility function $V(\mathbf{p},\mathbf{t},T,M,\mathbf{s})$ implied by utility maximization subject to the money and time budgets is defined as

$$(1) \qquad V(\mathbf{p},\mathbf{t},T,M,\mathbf{s}) \equiv \underset{\mathbf{x}}{Max}\ u(\mathbf{x},\mathbf{s}) + \lambda[M\text{-}\mathbf{px}] + \mu[T\text{-}\mathbf{tx}],$$

where λ is marginal utility of money and μ is the marginal utility of time.

The vector first order necessary conditions are

$$\mathbf{x}: u_{\mathbf{x}} \leq \lambda \mathbf{p} + \mu \mathbf{t}, \quad [u_{\mathbf{x}} - \lambda \mathbf{p} - \mu \mathbf{t}]\mathbf{x} = \mathbf{0}$$

(2) $$\lambda: M - \mathbf{p}\mathbf{x} = 0$$

$$\mu: T - \mathbf{t}\mathbf{x} = 0$$

For interior activity choices we obtain the usual result that marginal benefits are equal to marginal costs $u_{\mathbf{x}} / \lambda = \mathbf{p} + (\mu / \lambda)\mathbf{t}$. This condition differs from the single-constraint framework in that the marginal time cost is included on the cost side. The ratio of the marginal utility of money to the marginal utility of time μ / λ converts the time prices $\mathbf{t}$ into monetary terms. It will be convenient to denote this ratio ρ, where $\rho \equiv \mu / \lambda$. This ratio is the marginal money value of time, or the opportunity cost of time. Note that $\rho = V_T / V_M$ where $V_T \equiv \partial V / \partial T$ and $V_M \equiv \partial V / \partial M$.

In principle, the first order necessary conditions solve Marshallian activity demands as a function of money prices, time prices, money budget, and time budget. Hence, the optimal solution to equations (2) yields $\mathbf{x} = \mathbf{x}(\mathbf{p},\mathbf{t},M,T,\mathbf{s})$. The first order conditions also solve $\mu(\mathbf{p},\mathbf{t},M,T,\mathbf{s})$ and $\lambda(\mathbf{p},\mathbf{t},M,T,\mathbf{s})$, which implies that the marginal money value of time can be expressed as

(3) $$\rho(\mathbf{p},\mathbf{t},M,T,\mathbf{s}) \equiv \mu(\mathbf{p},\mathbf{t},M,T,\mathbf{s}) / \lambda(\mathbf{p},\mathbf{t},M,T,\mathbf{s}).$$

Because explicit solutions are difficult to derive, even for the simplest utility functions, an alternative representation of the optimal solution is useful for empirical implementation of two-constraint models. It can be shown that demands consistent with this framework are demands that are functions of full prices and full income, where time

prices and the time budget are converted into monetary terms by the marginal money value of time ρ, Larson and Shaikh (2001). This implies that we can express Marshallian activity demands as follows

(4) $\mathbf{x} \equiv \mathbf{x}(\mathbf{p},\mathbf{t},M,T,\mathbf{s}) \equiv \mathbf{x}(\mathbf{p}^{\mathbf{F}},M^{F},\mathbf{s})$,

which for the recycling activity vector can be written as

(4') $\mathbf{r} \equiv \mathbf{r}(\mathbf{p},\mathbf{t},M,T,\mathbf{s}) \equiv \mathbf{r}(\mathbf{p}^{\mathbf{F}},M^{F},\mathbf{s})$

The full price vector is defined as $\mathbf{p}^{\mathbf{F}} \equiv \mathbf{p} + \rho\mathbf{t}$ and full income is defined as $M^{F} \equiv M + \rho T$. In geneneral, estimation of demands requires simultaneously specification and estimation of the latent endogenous marginal money value of time in equation (3).[viii]

In this paper we derive an expression for the marginal money value of time, which, under certain assumptions, is consistent with observable variables in the dataset. This derivation is provided in appendix 1. We use this expression to econometrically estimate the marginal money value of time in a first-stage analysis. Regression results are provided in appendix 2. Predicted marginal money values of time from this stage are used to construct the utility-theoretic price and income variables. Section 5 presents second-stage results, which are the main focus of this paper. Here we estimate demands for recycling activites, equations (4'), as a function of full prices and full income, and other variables of interest.

3. DATA DESCRIPTION[ix]

Our primary data source is a nation-wide household survey conducted in 1999, Statistics Norway (1999). This survey contained a section of questions about recycling behavior, recycling motivations, and household characteristics. Representatives of 1,162 households completed the survey, resulting in a 58% participation rate. About 3/4 of the interviews were in-person while the rest were conducted by telephone. We linked this data with information on disposal fee systems and recycling programs implemented throughout the 435 Norwegian municipalities. This information is compiled by Statistics Norway on a bi-annual basis. In the below paragraphs, we describe our dataset in more detail. Descriptive statistics are provided in table 1.[x]

The dependent variables are recycling of cartons, paper, glass, metals, plastics, and food waste. The survey participants reported whether they recycle *none*, *some*, *most*, or *all* of each material.[xi] The participants were explicitly asked to exclude materials recycled through deposit-refund systems. For estimation of recycling activity demands, we group *some* and *most* into one type of response so that we have three ordered categories.[xii] Table 1 indicates that paper and glass are the most intensely recycled materials whereas recycling of plastics is less prevalent. Somewhat surprisingly, over a third of the respondents reported to be recycling *all* food waste. However, a peak at the indicator variable for curbside collection reveals that this material has been heavily targeted by policies with over half of our sample having access to curbside collection of food waste. Table 1 groups the exogenous variables into *policy variables* and *socioeconomic and other variables*. There are three types of policy variables: presence of

waste disposal fee, curbside collection, and drop-off collection. We discuss these in order.

A waste disposal fee constitutes an economic incentive for recycling. Unfortunately, we did not have information on the magnitude of this incentive in the different municipalities. We only know whether a waste disposal pricing system has been instituted. Moreover, a peculiarity of implementation of waste disposal fees in Norway is that while it is fairly widespread, many municipalities still offer a choice between fee differentiation and a fixed fee charged to the household's utility bill. We distinguish between whether survey participants lived in a municipality with 'voluntary' differentiation program (56% of the sample) versus 'mandatory' differentiation program (18% of the sample). Under both policy schemes, households have an economic incentive to reduce waste disposal in order to lower their disposal bills.

Curbside and drop-off recycling programs make it easier or more convenient for households to recycle. As we can see in table 1, drop-off programs are more common than curbside programs. Particularly noteworthy is that less than 5% of the sample has access to curbside collection of glass, metals, and plastics. This is however not that surprising, given the fact that deposit-refund recycling systems are very common in Norway, particularly for glass bottles and plastic bottles.

The socioeconomic variables show that the average survey participant was 44 years old, lived in a household with 2.75 members, and had income of 230,000NOK ($32,900) with household income of 390.000NOK ($55,700) per year. About 25% of the sample had university degrees, 58% lived in a single or detached house, 23% lived in a city, and about half were male. As far as the participants' labor market situation, 25%

held a management position, 46% worked in private sector, 7% had no formal vocational training, 2% were unemployed, 10% were retired, 7% were students, and only 2% stayed at home full-time.

The survey included six specific questions probing households' motivations for recycling. These questions were phrased as: *Do you agree, partially agree, partially disagree, or disagree with the following statements? I recycle because…"* Responses to these questions were converted into numeric values where *disagree* was set to zero, *partially disagree* was set to one, *partially agree* was set to two, and *agree* was set to three.

The first question, which received the lowest agreement score, was intended to capture whether households perceive recycling as enjoyable. The second question measures the extent to which recycling is felt as mandatory. We should point out that, to the best of our knowledge, none of the municipalities had implemented recycling mandates at the time of the survey. Questions 3-6 were intended to capture non-economic factors or intrinsic motivations, potentially related to the idea that there are complementary benefits associated with recycling (see Bruvoll and Nyborg (2002) and Bruvoll et al. (2002) for a discussion of these questions and their potential correspondence with various public good contribution models in economics). The idea that recycling is perceived as a public good is supported by the fact that 87% said they *think recycling contributes to a better environment.*

4. ECONOMETRIC SPECIFICATION

We apply a first-order approximation to the estimation of the household recycling demands, equations (4'). The full price variable and the full income variable are constructed through a first-stage estimation of the marginal money value of time (appendix 1 and appendix 2). Recycling of material *j* by household *i* is specified as a function of the full price of recycling, full income, disposal fee, recycling program attributes, and variables characterizing the household. We denote the matrix of right-hand-side variables by **z**. Hence, recycling activities are given by

$$r_{ij}^{*} = \boldsymbol{\alpha}_{j}^{'}\mathbf{z}_{ij} + \varepsilon_{ij}, \qquad j = 1,2,...,6$$

where r_{ij}^{*} is the latent or true recycling level. Instead of observing how much of each material is recycled, we observe whether the household recycles *none*, *some* or *most*, or *all* of material *j*. These responses are translated into three ordered categories 0,1,2. Thus, we have that

$$\begin{aligned} \tilde{r}_{ij} &= 0 \quad if \qquad r_{ij}^{*} = 0 \\ \tilde{r}_{ij} &= 1 \quad if \qquad 0 < r_{ij}^{*} \le \kappa_{j}, \\ \tilde{r}_{ij} &= 2 \quad if \qquad \kappa_{j} < r_{ij}^{*} \end{aligned}$$

where κ_{j} is the limit at which the respondents shift from recycling *some* or *most* to *all* of the material. We assume that the random error term ε_{ij} is distributed standard logistic,

independently across households and materials. The probability that we observe household *i* in a particular category is given by

$$\Pr(\tilde{r}_{ij} = 0) = \frac{1}{1 + e^{\boldsymbol{\alpha}_j' \mathbf{z}_{ij}}},$$

$$\Pr(\tilde{r}_{ij} = 1) = \frac{1}{1 + e^{-\kappa_j + \boldsymbol{\alpha}_j' \mathbf{z}_{ij}}} - \frac{1}{1 + e^{\boldsymbol{\alpha}_j' \mathbf{z}_{ij}}},$$

$$\Pr(\tilde{r}_{ij} = 2) = 1 - \frac{1}{1 + e^{-\kappa_j + \boldsymbol{\alpha}_j' \mathbf{z}_{ij}}}.$$

This is an ordered logit model that can be implemented by maximum likelihood estimation.

5. EMPIRICAL RESULTS

The estimated recycling demands are reported in table 2. This table provides the qualitative results, as reflected in the coefficients of the non-linear regressions. Quantitative results, as measured by the marginal effects of the exogenous variables on the probability of recycling *none*, *some* or *most*, or *all* of each material, are shown in table 3. This table only reports marginal effects for significant policy variables and the full price of recycling. The econometric estimation of the marginal money value of time can be found in appendix 2.

From table 2, we can see that all regressions are highly significant as indicated by the chi-square statistic. The within sample predictive power, as measured by proportions of correctly predicted outcomes or choices, is highest for food waste and paper and

smaller for cartons and metals. The ordered logit threshold parameters are significant and greater than zero, consistent with absence of model misspecification. The full price of recycling is significant in three of the regressions, suggesting that including the time aspect is important in explaining recycling behavior. The policy variables are generally significant, with either or both of the disposal fee variables significant in all regressions, and curbside recycling and drop-off recycling significant for four and three materials respectively. The demographic variables do not contribute much to the regressions, with the exception of urban location (live in City), which appears to have a significantly negative effect on recycling of three materials. The motivational questions are individually significant in several cases and their joint inclusion significantly improves explanatory powers and statistical efficiency of other parameter estimates.

When we consider all materials together, our results can be summarized as follows: Norwegian households are responsive to an economic incentive, in the form of differentiated disposal fees, and convenience, in the form of curbside and drop-off recycling programs. However, recycling does not have a zero own-price, as it requires a non-trivial time effort. Thus, the extent to which households are constrained on time is an important factor. Lastly, behaviors are also guided by other motivations that cannot be captured fully by the standard economic variables.

In the next five subsections we discuss disposal fees, recycling programs, the role of time, the demographic variables, and the motivational questions, respectively.

5.1. Waste Disposal Fees

A fee on waste disposal provides the households with an economic incentive to reduce waste disposal and subsequently their waste collection bills. Households can

reduce waste disposal by generating less waste in the first place or recycling more. In other words, recycling is an alternative or substitute waste handling option to waste disposal. The results in table 2 show that a waste disposal pricing system is a significant determinant of recycling for all materials. The strength of the impact of this policy variable can be seen in table 3. For example a voluntary fee differentiation reduces the probability of recycling *none* of the cartons by 13% and increases the probability of recycling *all* of this material by 15%. It is also clear that the effect of a waste disposal pricing policy varies from material to material. The results indicate that fee differentiation is particularly effective in the case of food waste but less so in the case of glass.

Our finding with respect to this policy variable contradicts a recent study of material-specific household recycling in the United States, Jenkins et al. (2003). These authors fail to find that a disposal fee affects recycling levels at all. While our study of Norway is believed to be the first, there are several existing studies of the effectiveness of disposal prices in the United States, see Jenkins et al. (2003) for details. The results of these studies are mixed. Our finding aligns for example with the conclusion of Callan and Thomas (1997) and Hong and Adams (1993).

5.2. Curbside and Drop-Off Recycling Programs

Curbside and drop-off programs are implemented to make it easier or more convenient for households to recycle. Table 2 indicates that both types of programs positively affect the recycling behavior of Norwegian households, with curbside recycling appearing to be the more effective program. The curbside recycling program indicators are significant in the regressions for paper, plastics, glass, and food waste. The

drop-off program indicators are significant in the cases of plastics, glass, and metals. Table 3 reinforces the impression that curbside recycling is the more effective program, as the marginal effects are generally higher. For example, both programs are significant in the plastics regression. A curbside program increases the probability that *all* plastics is recycled by 19% and reduces the probability that *none* of this material is recycled by 25%. In comparison, the marginal effects of a drop-off program on these probabilities are 6% and negative 8% respectively. As we also observed in the case of waste disposal fees, different materials are affected to varying degrees by these two programs. This may have important implications for solid waste policy makers and planners currently in the process of designing and implementing new or additional policy initiatives.

Our finding for these two policy variables collaborates the material-specific analysis in Jenkins et al. (2003). They also find that curbside recycling is more effective than drop-off recycling. However, in their study, both program variables are significant across all materials and their quantitative findings are generally stronger. Taken at face value, this finding, together with our finding on waste disposal fees, indicate that Norwegian consumers are more responsive to an economic incentive while U.S. households are more responsive to convenience.

5.3. Full Price and Full Income

Our estimated recycling demands reflect the notion that households are constrained by both money and time. Most often households can recycle materials through programs that have no money prices (aside from sometimes a fixed set-up fee). However, this does not mean that recycling is a 'free-lunch'. Our survey data indicate that households spend significant amounts of time in recycling-related activities. When

time constraints are binding, this implies that there is a non-trivial time cost of recycling, which will depend on the households' marginal money values of time. This is the *own-price* of recycling whereas a waste disposal fee can be thought of as a *substitute price*.

The main effect of including in our regressions a full price variable and a full income variable is improved statistical efficiency. These variables raised the explanatory power of the model and enhanced the significance levels of other theoretically relevant variables.[xiii] Moreover, the full price of recycling (which by our analysis in appendix 1 and appendix 2 is simply the marginal money value of time) is significant, with an expected negatively signed coefficient, in the regressions for paper, glass, and metals, as can be observed in table 2.[xiv] This result makes intuitive sense because these materials are potentially the most time-intensive. For one, our study ignores materials recycled through deposit-refund systems. This means that the glass and metals categories are likely to be dominated by containers used for food products. These containers could involve relatively time-intensive preparation, such as cleaning. Moreover, these materials can only be recycled through curbside programs by less than 5% of our sample. This means that transportation time could be significant. Paper products are also likely to involve time-intensive tasks, such as stacking, bringing to and from a storage place, and so on. In contrast, recycling of the other materials could be less time-intensive. For example, food waste, while messy, will often simply require separation from other wastes disposed. For these reasons, it seems reasonable that recycling of glass, metals, and paper is more responsive to the full price variable than the other materials.

Table 3 provides marginal effects of the full price variable on recycling of these three materials. At first glance, it may appear that these effects are trivial. However, it

should be noted that the reported marginal effects are associated with a 1NOK ($0.14) increase in the marginal money value of time. For example, an increase of 1NOK is associated with a 0.6% increase in the probability of recycling *none* and a 1.1% decrease in the probability of recycling *all* glass. Therefore, large increases in households' time values could have substantial adverse impacts on their recycling activities.

As pointed out in our introduction, most empirical studies of recycling behavior do not take explicitly into account the time aspect. So far, we have been able to compare our results with the analysis of Jenkins et al. (2003). However, they base their analysis on a one-constraint (money budget) utility maximization framework. Two studies that attempted to account for the own-price of recycling are Hong and Adams (1993) and Jakus et al. (1996). Both studies used the implied wage rate from an income variable to estimate the time cost of recycling. Hong and Adams (1993) find that overall recycling is inversely related to the implied value of time. In Jakus et al. (1996), a similar variable is significant for paper but not for glass recycling.

5.4. Demographic Variables

Of the demographic variables, household size appears to positively affect cartons recycling, living in a single or detached home has a positive impact on cartons and food waste recycling, while living in a city has a negative effect on recycling of glass, metals, and food waste.[xv]

Previous studies have found mixed impacts of demographics and more broadly socioeconomic characteristics. For example, Jenkins et al. (2003) find greater influences of such variables. In particular contrast to our results, they find that education level is an important determinant of household behavior. In general, we think it makes intuitive

sense that demographics play a lesser role in a study of Norwegian households. The population of Norway is much more homogeneous, in most respects, than the population of the United States.

5.5. Motivational Variables

In addition to being influenced by economic incentives and the presence of convenience, our regression results indicate that households' recycling choices are guided by many other factors as well. The statistical importance of the motivational questions suggests that households recycle out of pleasure, obligation, and to enjoy complementary benefits from perhaps contributing to a public good.

From table 2 we can see that the motivational question on the extent to which recycling is a *pleasant activity* is significant in all regressions. Although this question received the lowest agreement score in the survey, this result provides a justification for representing recycling explicitly as an argument of the utility function. The extent to which recycling is perceived as a *mandate from the government* has a positive impact on food waste and plastics but a negative impact on glass and metals. This suggest that policy makers and planners should be careful about implementing mandatory recycling or promoting it by appealing to such notions, as this may have the opposite of the intended effect. In this context, it is interesting to note that the full price of recycling was significant for glass and metals. This might imply that if recycling is perceived as mandatory, households choose to devote their effort to the relatively less time-intensive materials.

Questions 3 to 6 are potential indicators of the presence of complementary benefits from contributing to a public good. These four questions are individually

significant in several cases. Moreover, a likelihood ratio test performed for each regression rejected the null hypothesis that questions 3-6 are jointly insignificant. We take this result as support for the idea that complementary benefits from contributing to a public good are important to recycling choices.[xvi]

6. CONCLUDING REMARKS

In this paper we provided an analysis of the determinants of household recycling behavior in Norway. One major finding was that both an economic incentive, in the form of disposal fee differentiation, and convenience, in the form of curbside and drop-off recycling programs, are effective policies. However, these policies affected recycling of different materials to various degrees.

This paper attempted to take seriously the role of time, as a second constraint, in addition to the usual money constraint. We recognized that recycling activities are potentially time-intensive. While publicly provided recycling programs are free of charge, recycling is not costless unless households have non-binding time constraints. Our theoretical framework suggested that at the optimal solution, demands for recycling activities are functions of full prices and full income. Full prices and full income must reflect the marginal money value of time, which is only revealed by the wage rate under special conditions. Instead, behavioral and contingent valuation questions on the survey allowed us to derive and estimate the endogenous latent value of time, which was subsequently used in the estimation of recycling demands. We found that adding the time aspect improved statistical efficiency. Furthermore, the marginal money value of time was significant in three regressions.

We also investigated several so-called non-economic factors or intrinsic motivations. Of particular interest was the possibility that households are motivated to recycle by a desire to contribute to a public good. A set of motivational questions from our survey data, potentially reflecting the extent of such desire, were jointly significant in all regressions, lending support to the idea that recycling is more than just a waste handling option.

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APPENDIX 1: Conceptual Derivation of Marginal Money Value of Time

A contingent valuation question asked the survey participants their maximum annual willing to pay to have a company taking over the recycling responsibility on the household's behalf. The hypothetical situation was described to result in the same levels of recycling, and the same environmental impact, as the original situation. We denote the response to this question WTP^M, where the superscript *M* indicates *money* willingness to pay. Survey participants were also asked how many minutes they spend per week in recycling-related activities. We convert this response into number of hours per year, denoted by T_r. We will show that, under certain assumptions, these two pieces of information relate directly to the marginal money value of time.[xvii]

Recall from section 2 that the indirect utility function implied by utility maximization, subject to a money constraint and a time constraint, is a function of money prices, time prices, money budget, and time budget. We can write this function equivalently as a function of full prices and full income

$$V(\mathbf{p}, \mathbf{t}, T, M, \mathbf{s}) \equiv V(\mathbf{p}^{\mathbf{F}}, M^F, \mathbf{s}),$$

where we remind the reader that full prices are defined as $\mathbf{p}^F \equiv \mathbf{p} + \rho\mathbf{t}$ and full budget is defined as $M^F \equiv M + \rho T$.

Maximum money willingness to pay WTP^M can be defined implicitly using the right-hand-side of the above indirect utility identity

$$V^0(\mathbf{p}^{\mathbf{F}}, M^F - p_r^F T_r, \mathbf{q}^0) \equiv V^1(\mathbf{p}^{\mathbf{F}}, M^F - WTP^M, \mathbf{q}^1),$$

where a *zero* superscript indicates status quo, or the actual choice situation, and a superscript *one* indicates the hypothetical scenario, and only the subset **q** of the utility shifters **s** is explicitly recognized. In general, the perceived quality attributes of recycling (or equivalently, the complementary benefits of recycling) could differ under the actual and hypothetical situations.

We will first assume that the consumer is indifferent between the two quality vectors such that $\mathbf{q}^0 = \mathbf{q}^1 = \mathbf{q}$. Let us take warm glow of giving as an example of one of the attributes of recycling. This assumption implies benefits from this attribute are equally present in the two situations. This is realistic if the warm-glow benefits are derived from the contribution and not from its associated effort. Weak monotonicity of the indirect utility function in full income allows us to invert the above expression to obtain

$$M^F - p_r^F T_r + g(\mathbf{p^F}, \mathbf{s}, \mathbf{q}) \equiv M^F - WTP^M + g(\mathbf{p^F}, \mathbf{s}, \mathbf{q}) .$$

Further simplification of this expression yields

$$WTP^M = p_r^F T_r = (p_r + \rho t) T_r ,$$

which intuitively states that the maximum willingness to pay to have a company conducting the recycling is the total monetary costs of the recycling effort.

We next assume that the money prices of recycling are of second order importance and can be ignored. This seems realistic since households are rarely charged a monetary fee for participating in recycling programs. Normalization of the time price of recycling to unity allows us to express the marginal money value of time as the ratio of willingness to pay and the time spent recycling

$$\rho = WTP^{M} / T_{r}.$$

Hence, observable information can be used to infer the marginal money value of time, which in turn allows us to construct the full price of recycling and full income. Note that by our assumptions, the full price of recycling is simply the marginal money value of time, that is $P_r^F = \rho$. Full income consists of money income and the monetary value of the time budget, $M^F = M + \rho T$.

In appendix 2 we discuss several reasons why this measure is imperfectly observed in our dataset. To deal with these issues, we econometrically estimate the marginal money value of time only for a subset of our observations. Predicted values from this estimation are used to construct full price and full income for the entire sample.

APPENDIX 2: Estimation of the Marginal Money Value of Time

The respondents in our dataset presented two challenges to constructing a measure of marginal money value of time based on the analysis in appendix 1. Firstly, a subset of the respondents reported not to spend any amount of time in recycling related activities (additionally, for this reason, these participants were not administered the contingent valuation question). As a result, we cannot construct the marginal money value of time ratio WTP^M / T_r for this subset.

Secondly, many survey participants expressed zero willingness to pay in the contingent valuation question, but nevertheless reported significant recycling efforts. Taken at face value, this suggests that their marginal money value of time is zero. While it is certainly possible that some consumers feel they have non-binding time constraints, we believe that this is unlikely to be the case for the majority of these respondents. Instead we suggest two alternative explanations. Mistrust in the hypothetical situation, or aversion against the idea of a private firm taking over an activity that might be perceived as a personal responsibility, could lead to so-called *protest bidding*. Alternatively, it is possible that our assumption, that perveived quality attributes of recycling remain unchanged ($\mathbf{q}^0 = \mathbf{q}^1 = \mathbf{q}$), fails to hold for this group. Both of these explanations imply that the analysis in appendix 1 is not directly applicable for this subset.

To deal with these issues we adopt the strategy of estimating an econometric model for the marginal money value of time. We do so only for those reporting both a positive willingness to pay and a positive recycling effort. We then predict the marginal money value of time for the entire sample. These predicted values allow us to

subsequently construct the full price variable and the full income variable included in the demand estimation (section 5).

In accordance with Larson (2002) and following a similar approach as Larson and Shaikh (2001), we estimate the marginal money value of time as a function of demographic variables, including variables characterizing the respondent's labor market situation. We adopt a log-linear functional form, which ensures that predicted values are strictly positive, consistent with our belief that time constraints are generally binding. We estimate the model by ordinary least squares. Results are reported in the following table.

Ordinary Least Square Regression for Log Marginal Money Value of Time

Variable	Coefficient	Standard Error	P-Values
Constant	2.8081	0.2717	0.0000
Earnings Rate	0.0004	0.0005	0.3317
Age of Respondent	-0.0145	0.0056	0.0093
Household Size	-0.1174	0.0422	0.0057
(0,1) Indicator for College Degree or Above	0.0399	0.1359	0.7690
(0,1) Indicator for Management Position	0.4069	0.1529	0.0081
(0,1) Indicator for Private Sector	0.0617	0.1403	0.6603
(0,1) Indicator for Unemployed	0.1241	0.5042	0.8057
(0,1) Indicator for Staying at Home	-0.6442	0.4151	0.1214
(0,1) Indicator for Retired and Living off Pension	-0.2775	0.2468	0.2614
(0,1) Indicator for Student	0.5238	0.2050	0.0109
(0,1) Indicator for Unskilled	-0.4550	0.2285	0.0471
(0,1) Indicator for Male Respondent	0.1632	0.1211	0.1785

N=441, Adjusted R-Squared=0.11, F-Stat=5.34, P-Value=0.0000

Our results indicate absence of a correspondence between a person's earnings rate and his or her opportunity cost of time. Unfortunately, we did not have information to distinguish between respondents working flexible hours versus or fixed hours.

Intuitively, the value of time for people working flexible schedules is more likely to be connected to their earnings rate.

The significant variables are age, household size, and whether the respondent works in management, is a student, or unskilled labor. Age, household size, and being an unskilled labor appear to have a negative impact on the marginal money value of time. Managers and students seem to have higher values of time. For example, a one-year increase in age is associated with a 1.45% decline in the time value. Being a manager increases the value of time by about 41%.

The mean predicted marginal money value of time for the entire sample was 9NOK ($1.3). This is dramatically lower than the mean earnings rate of 116NOK ($16.6).

Table 1: Descriptive Statistics

VARIABLE	DESCRIPTIVE STATISTICS		
Dependent Variables:	***Percentage of Sample Recycling…***		
Recycled Materials	***None***	***Some/Most***	***All***
Cartons	32.66%	25.29%	42.05%
Paper	10.99%	19.42%	69.58%
Glass	18.78%	20.92%	60.30%
Metals	46.85%	19.96%	33.19%
Plastics	66.17%	14.19%	19.64%
Food Waste	52.40%	8.86%	38.74%
Independent Variables:	**Sample Mean**		**Standard Dev.**
(0,1) Policy Indicator Variables			
Voluntary Fee Differentiation	0.56		0.50
Mandatory Fee Differentiation	0.18		0.38
Curbside Collection of Cartons and Paper	0.88		0.32
Curbside Collection of Glass	0.03		0.16
Curbside Collection of Metals	0.02		0.13
Curbside Collection of Plastics	0.02		0.13
Curbside Collection of Food Waste	0.58		0.49
Drop-Off Program for Cartons and Paper	0.42		0.49
Drop-Off Program for Glass	0.92		0.28
Drop-Off Program for Metals	0.62		0.49
Drop-Off Program for Plastics	0.24		0.43
Drop-Off Program for Food Waste	0.08		0.27
Socioeconomic and Other Variables			
Household Income (in 1,000 NOK)	390.43		259.16
Respondent's Income (in 1,000 NOK)	231.02		515.28
Household Size	2.75		1.41
Age of Respondent	43.79		16.25
(0,1) Indicator for College Degree or Above	0.25		0.43
(0,1) Indicator for Single or Detached House	0.58		0.49
(0,1) Indicator for Live in City	0.23		0.42
(0,1) Indicator for Management Position	0.25		0.43
(0,1) Indicator for Private Sector	0.46		0.50
(0,1) Indicator for Unemployed	0.02		0.13
(0,1) Indicator for Staying at Home	0.02		0.15
(0,1) Indicator for Retired and Living off Pention	0.10		0.30
(0,1) Indicator for Student	0.07		0.26
(0,1) Indicator for Unskilled	0.07		0.26
(0,1) Indicator for Male Respondent	0.51		0.50
Recycling Motivations			
Do you think recycling contributes to a better environment?	0.87		0.34
Do you agree (3), partially agree (2), partially disagree (1) or disagree (0) with the following statements?			
1. I think recycling is a pleasant activity in itself	1.16		1.15

2. I consider recycling to be a mandate from the government	1.75	1.21
3. I want to think of myself as a responsible person	1.99	1.12
4. I want other people to think of me as a responsible person	1.16	1.22
5. I would like to contribute to a better environment	2.82	0.52
6. I should do what I would like other people to do	2.47	0.86

Table 2: Econometrics Results for Ordered Logit Model

Variable Name	Cartons	Paper	Plastics	Glass	Metals	Food Waste
Constant	-0.7710**	1.0197***	-1.6178***	0.2351	-0.2938	-1.5517***
	(0.3064)	(0.3143)	(0.3576)	(0.3129)	(0.2932)	(0.3664)
Full Price and Full Income:						
Full Price of Recycling	0.0085	-0.0210*	-0.0047	-0.0302**	-0.0251**	-0.0009
	(0.0099)	(0.0110)	(0.0116)	(0.0107)	(0.0103)	(0.0112)
Full Income	0.0000	0.0003	0.0000	0.0003	0.0002	-0.0003
	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0003)
Policy Variables:						
Voluntary Fee Differentiation	0.3789***	0.3728***	0.3975***	0.0543	0.1898*	0.4282***
	(0.0995)	(0.1144)	(0.1070)	(0.1069)	(0.1027)	(0.1103)
Mandatory Fee Differentiation	-0.0670	-0.1385	0.2208	0.2665*	0.3562**	0.7332***
	(0.1469)	(0.1695)	(0.1669)	(0.1588)	(0.1592)	(0.1802)
Curbside Recycling Program	0.1038	0.3009**	0.7038**	0.5716**	0.3519	1.1345***
	(0.1310)	(0.1462)	(0.3299)	(0.2839)	(0.2600)	(0.1147)
Drop-Off Recycling Program	-0.0582	-0.1538	0.2275**	0.3951***	0.2410**	0.2179
	(0.1283)	(0.1446)	(0.1147)	(0.1286)	(0.0950)	(0.5830)
Demograhic Variables:						
Household Size	0.0686**	-0.0328	-0.0097	-0.0109	-0.0058	0.0258
	(0.0299)	(0.0351)	(0.0320)	(0.0311)	(0.0307)	(0.0346)
Single or Detached House	0.1610*	0.0040	0.0771	-0.0808	0.0994	0.2722***
	(0.0874)	(0.0994)	(0.0977)	(0.0945)	(0.0895)	(0.0990)
College Degree or Above	0.1016	0.1224	-0.1387	0.0380	0.0766	-0.0448
	(0.0952)	(0.1186)	(0.1056)	(0.1009)	(0.0991)	(0.1187)
Live in City	0.0364	-0.2084	-0.2235	-0.2928*	-0.6574***	-1.1450***
	(0.1606)	(0.1826)	(0.1805)	(0.1728)	(0.1734)	(0.1781)
Recycling Motivations Questions:						
1. I think recycling is a pleasant activity in itself	0.1352***	0.0734*	0.1114***	0.1328***	0.1681***	0.1629***
	(0.0371)	(0.0444)	(0.0395)	(0.0417)	(0.0374)	(0.0429)
2. I consider it to be a mandate from the government	-0.0455	-0.0421	0.0710*	-0.0821**	-0.0623*	0.0896**
	(0.0338)	(0.0396)	(0.0377)	(0.0369)	(0.0357)	(0.0411)
3. I want to think of myself as a responsible person	0.0403	0.0252	0.0165	0.0390	0.1232**	-0.0354
	(0.0412)	(0.0510)	(0.0463)	(0.0462)	(0.0434)	(0.0498)
4. I want other people to think of me as a responsible person	0.0166	0.0272	0.1050**	0.0453	0.0737*	0.0635
	(0.0381)	(0.0474)	(0.0409)	(0.0437)	(0.0387)	(0.0450)
5. I would like to contribute to a better environment	0.0844	0.0133	0.1892*	0.2605***	-0.0343	0.2018*
	(0.0906)	(0.0951)	(0.1077)	(0.0854)	(0.0886)	(0.1095)
6. I should do what I would like other people to do	0.1188**	0.0721	0.0426	-0.0113	0.0481	-0.1090
	(0.0507)	(0.0583)	(0.0580)	(0.0544)	(0.0517)	(0.0686)
Ordered Logit Threshold Parameter	0.7375***	0.9539***	0.4854***	0.7681***	0.5969***	0.3322***
	(0.0431)	(0.0716)	(0.0397)	(0.0506)	(0.0402)	(0.0354)
Model Performance:						
Unrestricted Log-Likelihood	-892.165	-609.400	-738.073	-747.566	-856.896	-628.308
Restricted Log-Likelihood	-937.340	-632.260	-786.048	-786.990	-926.184	-817.648
Chi Square Statistic	90.351***	45.720***	95.950***	78.848***	138.578***	378.752***
Correct Predictions	442/876	644/876	574/876	568/876	468/876	619/876

Standard errors are reported in parentheses. *,**,*** indicate significance at the 90%, 95%, 99% level of confidence respectively.

Table 3: Marginal Effects of Significant Policy Variables and the Full Price of Recycling[+]

Variable Name	Cartons	Paper	Plastics	Glass	Metals	Food Waste
Voluntary Fee Differentiation						
Change in Probability of: Recycling *None*	-0.1266	-0.0406	-0.1466		-0.0745	-0.1706
Recycling *Some or Most*	-0.0230	-0.0792	+0.0391		+0.0052	+0.0119
Recycling *All*	+0.1496	+0.1199	+0.1075		+0.0693	+0.1587
Mandatory Fee Differentiation						
				-0.0555	-0.1399	-0.2921
Recycling *Some or Most*				-0.0437	+0.0098	+0.0204
Recycling *All*				+0.0992	+0.1301	+0.2717
Curbside Recycling Program						
Change in Probability of: Recycling *None*		-0.0328	-0.2595	-0.1191		-0.4520
Recycling *Some or Most*		-0.0639	+0.0692	-0.0937		+0.0315
Recycling *All*		+0.0967	+0.1903	+0.2128		+0.4205
Drop-Off Recycling Program						
Change in Probability of: Recycling *None*			-0.0839	-0.0823	-0.0947	
Recycling *Some or Most*			+0.0224	-0.0648	+0.0067	
Recycling *All*			+0.0615	+0.1471	+0.0880	
Full Price of Recycling						
Change in Probability of: Recycling *None*		+0.0023		+0.0063	+0.0099	
Recycling *Some or Most*		+0.0045		+0.0049	-0.0007	
Recycling *All*		-0.0067		-0.0112	-0.0092	

[+]Marginal effects are calculated at sample means. For the indicator variables (all but the full price of recycling), the marginal effects are calculated by setting the variable of interest to one and zero, with all other variables set at mean values, and taking the difference in the probabilites.

i Some regional studies of material specific recycling are Jakus et al. (1996), Reschowsky and Stone (1994), and Saltzman et al. (1993). Van Houtven and Morris (1999), Hong and Adams (1999), and Nestor and Podolsky (1998) study total recycling at the household level while Kinnaman and Fullerton (2000) and Callan and Thomas (1997) analyze recycling at the aggregate level.

ii Two notable exceptions are Jakus et al. (1996) and Hong and Adams (1993). The former analyzes drop-off recycling in a rural community while the latter analyzes curbside recycling in a metropolitan area. Both studies infer the wage rate from income data as a measure of the household's opportunity cost of time.

iii This value may or may not be equal to the wage rate depending on the household's labor market situation and whether work-time enters into the utility function or not. The opportunity cost of time is a central discussion in the recreational demand literature where the correctness of demand estimation and welfare measures hinges on the proper treatment of the value of time, see Larson and Shaikh (2001) and Lew and Larson (2002).

iv The use of so-called psycometric data is common in other sciences as well as in market research and more generally in economic research on latent classes where the objective is to account for consumer heterogeneity.

v In general, some activities are relatively time-intensive while other activities are money-intensive. There are two special cases. An activity could require no (or a trivial amount of) time, but have a positive money-price. At the other extreme, an activity could have zero money-price but a significant time-price. Our model explicitly recognizes the possibility that the household obtains utility from its recycling activities. However, because these activities require non-trivial time effort, the household must make an optimal choice between recycling other non-work activities.

vi A suffcient condition for stricty binding constraints are the presence of a time numeraire activity and a money numeraire activity with nonsatiation.

vii Specifically, we consider the possibility that the household considers recycling to be a public good contribution. We assume that private benefits associated with public good contribution can be represented by utility shifter. Such benefits may include warm glow of giving, social status, and self-image or identity as a moral person. The strength of such benefits will vary from household to household depending on the importance attached to the activities. Weak complementarity ensures that these attributes will be arguments of the consumer's indirect utility function and activity demands. This complementary relationship suggests that benefits from these attributes are only enjoyed when the associated activities are chosen.

viii As a special case, if the work schedule is fully flexible, work is compensated at a constant rate, and work provides no utility or disutility, then the marginal money value of time is exogenous, revealed by the wage rate.

ix See Bruvoll and Nyborg (2002) or Bruvoll et al. (2002) for more information.

x For our analysis, we exclude observations missing key pieces of information as well as those households who did not have any recycling options.

xi A problem with these variables is that the respondents reported their personal recycling activities while we wish to study household recycling. For our analysis, we make the heroic assumption that the respondent's recycling effort is representative of his or her household.

xii Results presented in section 5 are robust with respect to whether a 3-category or 4-category ordered model was estimated.

xiii One might go as far as to argue that ignoring the time aspect leads to omitted variable bias in the estimations.

xiv Ideally, we should account for uncertainty or error in prices and income arising from the fact that these were constructed by first estimating the marginal money value of time. For this reason, our standard errors are likely to be inflated. We by-pass this econometric issue in this version of the paper.

xv We excluded the age variable due to high multicolinearity with the full price of recycling. This problem was likely induced in the first-stage analysis, where age played a prominent role in explaining the marginal money value of time. We believe it is correct to leave out the age variable in favor of the theoretically relevant full price variable.

xvi *I want to think of myself as a responsible person* may relate to self-image or identity benefits. *I want other people to think of me as a responsible person* could be an indication of social approval or status seeking. *I would like to contribute to a better environment* signals the perceived environmental importance of recycling. It seems reasonable to think that potential warm-glow benefits would be conditional on a high score to this question. Although it could be argued that the idea of warm-glow is also consistent with questions 3 and 6. *I should do what I would like other people to do* is consistent with a moral motivation.

[xvii] Please see Bruvoll et al. (2002) for more details on these survey items.