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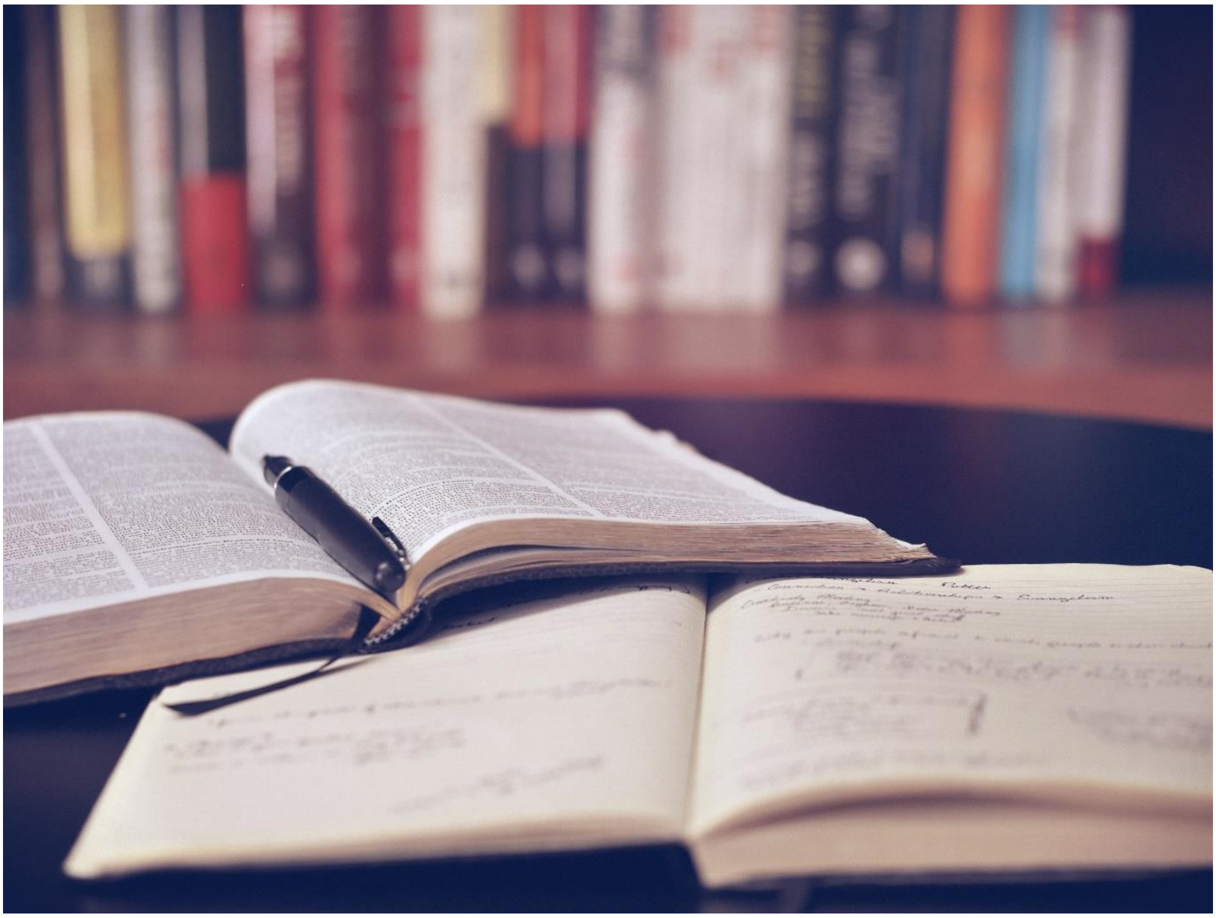

Time for Waste, Waste of Time? Assessing Heterogeneous Values of Time Spent Recycling Using a Latent-Class Rank-Ordered Logit Approach

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Abstract

Although the opportunity cost of time spent recycling has long been recognized as a key determinant of household recycling participation, very few empirical studies have attempted to provide estimates of it. In this paper, we propose a model of household recycling that, while including pecuniary and non pecuniary motives for decisions, such as social and moral norms or warm-glow, reveals heterogeneous values of saving time from recycling (VSTR). The predictions of our model are being tested, extending the basic latent-class logit model to the latent-class ranked ordered model and using data from a discrete choice experiment on waste management conducted in 2008 in Corsica. We find VSTR clearly heterogeneous across individuals, ranging from 8% to 76% of one's income.

1 Introduction

Although the opportunity cost of time spent recycling has long been recognized as a major determinant of households' recycling behavior, very few empirical studies have attempted to provide estimates of it. This is in contrast to the long tradition of literature on the value of travel time. Indeed, from Cesario (1976) who retained a value of one-third the average wage rate to Fezzi *et al.* (2014) who give subtle insights into the distribution of the value of travel time to recreation site, much progress has been made on the distribution of the so-called value of travel time.

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In the field of waste economics, a notable exception is the work of Halvorsen (2008), in which the opportunity cost of time spent recycling is approximated by the household's stated willingness-to-pay for leaving recycling to others. However, to date, there are no direct estimates of the opportunity cost of time spent recycling.

Our paper contributes to the waste management literature in two main ways. First, in the spirit of the models of time allocation, we propose a theoretical framework *à la* DeSerpa (1971), in which households' recycling level is influenced by non-pecuniary motives, such as social and moral norms. We then obtain a value of saving time from recycling (VSTR) corresponding to the difference between the value of time as a resource and the value of time spent recycling (the value of time as a commodity in DeSerpa's (1971) terms) that can be linked to individual preferences regarding recycling and to the unit cost of recycling. Therefore, the VSTR is individual-specific. Second, the predictions of the theoretical model are tested using data from a choice experiment on waste management conducted in 2008 in Corsica. A representative sample of the Corsican population was surveyed (481 individuals). Each respondent had to rank six waste management options defined by three attributes: environmental impact, time spent recycling each week, and monetary cost (change in annual waste fee per household). Combining the latter two attributes allows us to assess the individual VSTR. Estimating a latent-class rank-ordered logit model, we find that a two-class model better fits the data. The class shares are approximately 34% and 66%. Individuals belonging to each of the classes react to the cost and time attributes as expected; however, class-one individuals do not acutely distinguish the levels of environmental degradation. Indeed, individuals belonging to class one only have a positive willingness-to-pay for a low, or very low degradation. Finally, in line with the theoretical model, we observe heterogeneous VSTR, ranging from 8% to 76% of one's income.

The rest of the paper is organized as follows. Section 2 offers a brief history of the value of time departing from the seminal work of Becker (1965) and the previous papers on the specific topic of the valuation of the opportunity cost of time spent recycling. Section 3 presents the theoretical framework of the paper on the basis of DeSerpa's (1971) model. Section 4 describes the methodological empirical approach, which combines a discrete choice experiment and a latent-class rank-ordered logit model. The survey design, data and results are presented and discussed in Section 5. Section 6 concludes the paper and draws some policy implications.

2 A brief history of the value of time and applications to recycling

At the very beginning was the seminal contribution of Becker (1965), "[...] the foundational modelling framework for virtually all modern household level analyses of consumption and time use" according to

Chiappori and Lewbel (2015, p. 410). In his contribution, Becker (1965) argues that different types of time should have different shadow prices, contrary to what is found in most of the current models of time allocation, which assume a single wage rate associated with each individual's time. However, in Becker's (1965) model, utility does not directly depend on time required for consumption activities. Indeed, in Becker (1965), households "[...] combine time and market goods to produce [...] basic commodities that directly enter their utility functions" (Becker, 1965, p. 495). In short, households combine basic commodities to maximize a utility function subject to a budget constraint and a time constraint. Thus, in Becker (1965), time enters indirectly the utility as an input to prepare basic commodities but not as a direct argument. In contrast, DeSerpa (1971) postulates a utility function that depends on all households' consumption of goods and time activities allocation (alternative time-allocation models are presented using a canonical model by Jara-Díaz, 2000, p. 308-9). In so doing, DeSerpa (1971) extends Becker's model by allowing the individual value of (saving) time to be activity specific.

Building on the DeSerpa model, Cesario (1976) addresses the topic of the value of time in recreation benefit studies. On the basis of a review of the empirical results regarding the value of travel time provided by transport economics, Cesario (1976) retains a value of travel time (value of saving time) to recreation sites equal to one-third the wage rate. In the travel cost method literature, this latter value is sometimes presented as a recommendation taken from Cesario's paper. However, Cesario (1976, p. 38, note 17) himself states that this value is arbitrary and "[...] was chosen for convenience". He also states "[...] that the value of time for any individual will undoubtedly fluctuate dramatically over the course of even one day" (Cesario, 1976, p. 34, note 6). Thus, the value equal to one-third the wage rate was chosen because of data limitations and a lack of empirical work regarding the value of saving time.

Basically, what is called the value of time is the value of saving time. To quote Fezzi *et al.* (2014, p. 61), "This notion presupposes that time can be saved and transferred to another use which generates greater utility". Thus, the value of time stems from time-money trade-offs.

In the field of household economics, at least two papers address the willingness to spend time and money to obtain environmental improvements. In Eom and Larson (2006), the basic idea is to ask individuals not only their willingness-to-pay for clearly stated water quality improvements, but also whether they would accept increases in housework time related to water quality-improving actions (*e.g.*, changes in food preparation, in disposal practices, water uses). Matsumoto (2014) also uses a household production approach. He shows that the opportunity cost of time (based on a wage- and reservation wage-based approach) does influence the decision to undertake pro-environmental time-consuming activities (the purchase of refillable products). The theoretical foundations of the household production approach is again Becker's or DeSerpa's model of time allocation.

A series of papers, although primarily focused on the influence of personal motives, norms or the warm-glow effect on recycling behavior, also seek to assess how the opportunity cost of time spent recycling influences household recycling (Bruvoll *et al.*, 2002; Berglund, 2006; Halvorsen, 2008).

These papers have two main features in common. First, the theoretical framework is a model of time allocation *à la* Becker (1965) or *à la* DeSerpa (1971), which includes variables aimed at capturing the effect of social norms, personal motives and the effect of the opportunity cost of time spent recycling on household recycling (*e.g.*, decision to recycle, recycling intensity). Second, the opportunity cost of time spent recycling is empirically measured by collecting information about the actual time spent recycling **and** by asking the individuals how much they are willing to pay to leave recycling to others. These papers use typical contingent valuation techniques (*e.g.*, open-ended question, single- or double-bounded discrete choice) to elicit the willingness-to-pay to leave recycling to others.

Hage *et al.* (2009) also present the same type of model. However, the opportunity cost of time spent recycling is approximated by some distance variables, such as distance to recycling stations, access to a car, access to a system for property close collection.

Likewise, Abbott *et al.* (2013) present a theoretical model that includes the opportunity cost of time spent recycling as a determinant of household recycling. However, they do not have any data to test their theoretical model regarding the time spent recycling that could allow measuring its empirical impact.

In summary, the waste management literature acknowledges that the opportunity cost of time spent recycling is a major determinant of household recycling, but it does not provide clear results regarding the value of saving time from recycling and its distribution.

3 Building on DeSerpa's model: a theoretical framework of the value of saving time from recycling

Let $C_i > 0$ be a composite good consumption by individual i; $i = \{1, ..., n\}$; and $p_C > 0$ is the monetary cost of consumption; $R_i \geqslant 0$ is the level of recycling activity and p_R and t_{R_i}, respectively, are the monetary cost (*e.g.*, reflecting the cost of inputs, such as water used to clean waste, or the opportunity cost of devoting space to in-home waste storage) and the time spent on recycling activity by individual i with $(p_R, t_{R_i}) \geqslant (0, 0)$. As in Fezzi *et al.* (2014), we consider short-run choices: labor-market decisions are given and $t_{Li} > 0$ is the leisure time (time out of work) of individual i.

The utility-maximization problem[1] can be written as follows:

$$\underset{C_i,L_i,R_i,t_{Li},t_{Ri}}{Max} U_i\left(C_i, R_i, Q, S_i, t_{Li}, t_{Ri}\right) \tag{1}$$

subject to the following constraints:

$$N_i - \overline{p}_C C_i - \overline{p}_R R_i = 0 \tag{2}$$

$$T_i - t_{Li} - t_{Ri} = 0 \tag{3}$$

$$t_{Ri} \geqslant a_R R_i \tag{4}$$

$$R_i \leqslant \delta C_i \tag{5}$$

In the model, we assume that recycling is derived from four motives: a warm-glow effect, environmental concerns, social norms and a pecuniary motive. As in Andreoni (1990) and Abbott *et al.* (2013), we define the warm-glow effect as purely intrinsic. Nevertheless, in Abbott *et al.* (2013), the warm-glow effect is defined as the marginal utility of time spent recycling, whereas, within a framework of a household utility maximization model consistent with the DeSerpa (1971) model, we give (see below) a different interpretation to the marginal utility and define the warm-glow effect from recycling as the enjoyment that individual i derives from the activity of recycling itself, independently of its impacts on environmental quality and compliance with a social norm. Accordingly, the warm-glow effect in the model is measured by the direct effect of recycling on the utility level of individual i: $\frac{\partial U_i}{\partial R_i}(\cdot)$. Thus, the warm-glow effect that we assume is actually close to the original in Andreoni (1990).

Additionaly, in the model, recycling activities are not only valuable *per se* but also, on one hand, valuable for their impacts on households' monetary costs and, on the other hand, for their impacts on environmental quality and peer approval which affect the utility. Environmental quality depends on the level of households' recycling (by means of an increasing function $g\left(R_j\right)$) and on the exogenous impact on environmental quality of the waste management level q (by means of an increasing function $X\left(q\right)$).

Thus, the environmental quality is written as

$$Q = \sum_{j=1}^{n} g\left(R_j\right) + X\left(q\right) = g_{-i} + g\left(R_i\right) + X\left(q\right) \tag{6}$$

[1] The utility function of individual i is increasing in all its arguments (except possibly for t_{R_i}, for which $\frac{\partial U_i}{\partial t_{R_i}}(\cdot) \gtreqless 0$) and strictly concave.

where $g_{-i} \equiv \sum_{\substack{j=1 \\ j \neq i}}^{n} g(R_j)$; $g(0) = 0$; $g'(R_i) > 0$; $g''(R_i) \leqslant 0$; $X(0) = \overline{X}$; $X'(q) > 0$ and $X''(q) \leqslant 0$.

Peer-Approval $S_i(\chi_i)$, as in Abbott *et al.* (2013), captures the influence of a social norm $\overline{R}_i$ corresponding to the average recycling level for the reference group of i, where $\chi_i \equiv R_i - \overline{R}_i$ and where $S_i'(\chi_i) > 0$ if $\chi_i < 0$; $S_i'(\chi_i) \geqslant 0$ if $\chi_i \geqslant 0$; $S_i''(\chi_i) \leqslant 0$.

The last motive that individuals have to recycle comes from the economic incentives related to waste management fees. These are composed of two parts: a fixed (on a weekly basis) part $\tau_i > 0$ and a proportional unit fee on the discharged waste $p_d \geqslant 0$. Let $\delta \in]0, 1[$ be the fraction (assumed constant) of the composite consumption good that becomes waste. As stated above, we consider a short-run perspective. Therefore, we can assume that individuals facing a unit fee on waste do recycle to save part of the corresponding cost. Obviously, in a long-run perspective, it seems more likely that individuals also change their consumption behavior, especially in terms of consumed goods, to prevent waste generation. Considering for simplification purposes that δC_i is totally recyclable, it is straightforward that, on a strictly pecuniary basis, when $p_d > 0$, the choice to recycle all the recyclable material rather than discharge waste is made only if $p_d > \frac{1}{2} p_R$. Accordingly, if $p_d = 0$ (as is, to date, the case in Corsica, where the survey presented in this paper was conducted), recycling behaviors are mainly based on non-pecuniary motives.

Eq. (2) is the binding budget constraint of household i. In this constraint, $N_i \equiv I_i - \tau_i$ corresponds to the weekly available income of i, where I_i is the weekly income of i. $\overline{p}_C = p_C + \delta p_d$ is the total unit cost of consumption and $\overline{p}_R = p_R - \delta p_d$ corresponds to the net unit cost of recycling.

Eq. (3) is a binding time constraint, meaning that the sum of the amounts of time allocated to leisure and recycling is equal to the total (out of work or excess leisure) time available T_i. It is notable (see DeSerpa, 1971, p. 829) that the binding budget constraint and the binding time constraint are independent of each other and, in our model, this implies that the parametric time price of recycling is absent from the binding time constraint.

Eq. (4) is a time consumption constraint. This constraint indicates that the time allocated to recycling is equal to or greater than the minimum amount of time required to reach the amount of recycling R_i. Assuming a linear relation between $a_R > 0$, the minimum amount of time required to obtain one unit of recycled material, and the amount R_i and t_{Ri}, two cases are possible. The time recycling constraint is not binding if recycling is a leisure good and binding if recycling is an intermediate good in the terminology used by DeSerpa (1971). The time spent on recycling, as for any activity in the DeSerpa (1971) framework, is "[...] partly a matter of choice and partly a matter of necessity" (DeSerpa, 1971, p. 830). Obviously, as noted by DeSerpa (1971, p. 830): "Whether the equality is binding or not is a matter of individual preference, although common experience suggests that the constraint will be binding for nearly all individuals in certain activities, due to the nature of these activities". Additionaly, because most of the empirical studies find that time spent recycling is considered a burden (Bruvoll *et al.*, 2002; Berglund, 2006; Halvorsen, 2008[2]), we can conjecture that this constraint is binding for recycling activities. Note that various waste management options could be associated with various unit costs of recycling (p_R) and various technological parameters a_R.

The Lagrangian for this problem is as follows:

$$\begin{aligned}&\mathcal{L}\left(C_i, R_i, Q, S_i, t_{Li}, t_{Ri}\right)\\&= U_i\left(C_i, R_i, Q, S_i, t_{Li}, t_{Ri}\right) + \lambda_i\left(N_i - \overline{p}_C C_i - \overline{p}_R R_i\right) + \mu_i\left(T_i - t_{Li} - t_{Ri}\right) + \eta_{R_i}\left(t_{Ri} - a_R R_i\right) + \gamma_i\left(\delta C_i - R_i\right)\end{aligned}$$

In this function, λ_i and μ_i, respectively, represent the marginal utility of money and time. The Kuhn-Tucker multiplier η_{R_i} associated with the time recycling constraint represents the marginal utility of reducing the minimum time constraint of R_i, *i.e.,* the marginal utility due to relaxing the "technological constraint" (4). As stated above, recycling is an intermediate good ($\eta_{Ri} > 0$). Finally, γ_i is the Kuhn-Tucker multiplier associated with the upper bound constraint on recycling, thus representing the marginal utility of relaxing the upper bound constraint on recycling.

Denoting $\frac{dU_i}{dR_i} \equiv \frac{\partial U_i}{\partial R_i}(\cdot) + \frac{\partial U_i}{\partial Q}(\cdot)\, g'(R_i) + \frac{\partial U_i}{\partial S_i}(\cdot)\, S_i'(\chi_i)$ the total marginal impact of recycling on utility, $\frac{\partial U_i}{\partial R_i}(\cdot)$ is the warm-glow effect, $\frac{\partial U_i}{\partial Q}(\cdot)\, g'(R_i)$ is the environmental concerns effect and $\frac{\partial U_i}{\partial S_i}(\cdot)\, S_i'(\chi_i)$ is the peer-approval effect.

The corresponding first-order conditions for a maximum are

$$\frac{\partial \mathcal{L}}{\partial C_i}(\cdot) = \frac{\partial U_i}{\partial C_i}(\cdot) - \lambda_i \overline{p}_C + \delta\gamma_i = 0 \Longleftrightarrow \frac{\partial U_i}{\partial C_i}(\cdot) = \lambda_i \overline{p}_C - \delta\gamma_i \tag{7}$$

$$\frac{\partial \mathcal{L}}{\partial R_i}(\cdot) = \frac{dU_i}{dR_i} - \lambda_i \overline{p}_R - \eta_{R_i} a_R - \gamma_i \leqslant 0;\; R_i \geqslant 0;\; R_i \frac{\partial \mathcal{L}}{\partial R_i}(\cdot) = 0 \tag{8}$$

$$\frac{\partial \mathcal{L}}{\partial t_{Li}}(\cdot) = \frac{\partial U_i}{\partial t_{Li}}(\cdot) - \mu_i = 0 \Longleftrightarrow \frac{\partial U_i}{\partial t_{Li}}(\cdot) = \mu_i \tag{9}$$

$$\frac{\partial \mathcal{L}}{\partial t_{Ri}}(\cdot) = \frac{\partial U_i}{\partial t_{Ri}}(\cdot) - \mu_i + \eta_{R_i} \leqslant 0;\; t_{Ri} \geqslant 0;\; t_{Ri} \frac{\partial U_i}{\partial t_{Ri}}(\cdot) = 0 \tag{10}$$

$$N_i - \overline{p}_C C_i - \overline{p}_R R_i = 0;\; \lambda_i > 0;\; \lambda_i\left(N_i - \overline{p}_C C_i - \overline{p}_R R_i\right) = 0 \tag{11}$$

[2] Czajkowski *et al.* (2014) is a notable exception. Using data from a choice experiment conducted in a Polish municipality, the authors find that most respondents prefer to sort waste themselves instead of leaving recycling to a specialized sorting facility.

$$T_i - t_{Li} - t_{Ri} = 0;\ \mu_i > 0;\ \mu_i\left(T_i - t_{Li} - t_{Ri}\right) = 0 \tag{12}$$

$$t_{Ri} - a_R R_i \geqslant 0;\ \eta_{R_i} \geqslant 0;\ \eta_{R_i}\left(t_{Ri} - a_R R_i\right) = 0 \tag{13}$$

$$\delta C_i - R_i \geqslant 0;\ \gamma_i \geqslant 0;\ \gamma_i\left(\delta C_i - R_i\right) = 0 \tag{14}$$

Let us first study interior solutions in terms of recycling. In that case, because $R_i > 0$, thus $t_{Ri} > 0$ as well. Eqs. (10) and (14) imply

$$\begin{cases} \frac{dU_i}{dR_i} = \lambda_i \overline{p}_R + \eta_{R_i} a_R \text{ if } 0 < R_i < \delta C_i \\ \frac{dU_i}{dR_i} = \lambda_i \overline{p}_R + \eta_{R_i} a_R + \gamma_i \text{ if } R_i = \delta C_i \end{cases} \Longleftrightarrow \begin{cases} \frac{\frac{dU_i}{dR_i}}{\lambda_i} = \overline{p}_R + \frac{\eta_{R_i}}{\lambda_i} a_R \text{ if } 0 < R_i < \delta C_i \\ \frac{\frac{dU_i}{dR_i}}{\lambda_i} = \overline{p}_R + \frac{\eta_{R_i}}{\lambda_i} a_R + \frac{\gamma_i}{\lambda_i} \text{ if } R_i = \delta C_i \end{cases} \tag{15}$$

Additionaly, Eq. (10) gives: $\frac{\partial U_i}{\partial t_{Ri}}(\cdot) = \mu_i - \eta_{R_i}$.

Applying DeSerpa's (1971) approach, we can define the value of time spent recycling for individual i as his/her marginal rate of substitution of time spent on recycling activities for money, which is called the "value of time as a commodity" by DeSerpa (1971):

$$\frac{\frac{\partial U_i}{\partial t_{R_i}}(\cdot)}{\lambda_i} = \frac{\mu_i}{\lambda_i} - \frac{\eta_{R_i}}{\lambda_i} \Longleftrightarrow VSTR_i \equiv \frac{\eta_{R_i}}{\lambda_i} = \frac{\mu_i}{\lambda_i} - \frac{\frac{\partial U_i}{\partial t_{R_i}}(\cdot)}{\lambda_i} \tag{16}$$

Remembering that $\lambda_i = \frac{dU_i(\cdot)}{dN_i}$ and $\mu_i = \frac{dU_i(\cdot)}{dT_i}$, the ratio $\frac{\mu_i}{\lambda_i}$ corresponds to the marginal rate of substitution of time for money and is called the "value of time as a resource" by DeSerpa (1971).

Thus, the value of time spent recycling is the difference between the value of time as a resource and the value of saving time from recycling ($\frac{\eta_{R_i}}{\lambda_i}$) which is specific to this activity but also to each individual. The VSTR is greatly important for the evaluation of the benefits of policies aimed at reducing the minimum amount of time required to recycle, for example by improving collection and recycling infrastructures. Indeed, the VSTR represents the positive value of saving time from recycling presupposing that this time can be transferred to some alternative usage of greater value (leisure in our model; see Bates (1987) for an enlightening interpretation of multipliers and constraints within time allocation models). The VSTR is the only one of the three components of Eq. (16) to have an empirical content: "Neither the assumption nor [the] implication of [the value of time as a resource] is empirically verifiable, for utility is not measurable in any meaningful sense and [$\frac{\mu_i}{\lambda_i}$] cannot be related to any set of empirical data. On the other hand, a relationship can be derived between the measure, [$\frac{\eta_{R_i}}{\lambda_i}$], and empirically observable data" (DeSerpa, 1971, p. 835). The value of saving time from recycling can be interpreted as the willingness-to-pay of individual i to reduce the constrained time assigned to recycling.

Therefore, for an interior solution, Eq. (15) implies that the optimal level of recycling is obtained when the marginal rate of substitution of recycling for money is equal to the net unit cost of recycling plus the value of saving time from recycling times the technological parameter a_R ($\frac{\gamma_i}{\lambda_i}$ is added when the upper bound constraint on recycling is binding).

Moreover, combining Eqs. (15) and (16), we can relate the VSTR of individual i to his/her marginal rate of substitution of recycling for money and the net unit cost of recycling. Indeed, in the case of interior solutions optimality requires that

$$\begin{cases} \frac{\frac{dU_i}{dR_i}}{\lambda_i} = \overline{p}_R + a_R VSTR_i \text{ if } 0 < R_i < \delta C_i \\ \frac{\frac{dU_i}{dR_i}}{\lambda_i} = \overline{p}_R + a_R VSTR_i + \frac{\gamma_i}{\lambda_i} \text{ if } R_i = \delta C_i \end{cases} \tag{17}$$

Eq. (17) shows that optimality requires that the marginal rate of substitution of recycling for money equates with the total marginal cost of recycling, that is, the net unit cost of recycling plus the VSTR times the technological parameter a_R (again, $\frac{\gamma_i}{\lambda_i}$ is added when the upper bound constraint on recycling is binding). Thus, the higher the marginal rate of substitution of recycling for money (including the warm-glow effect, the environmental concerns effect and the peer-approval effect) of an individual is, the higher his/her VSTR is.

Obviously, individuals can in fact decide not to recycle. In our model, such a decision corresponds to a corner solution. In this case $Ri = 0$ and $t_{Ri} = 0$ (it must be noted that $t_{Ri} = 0$ can only occur in this case) and $\gamma_i = 0$. According to Eq. (10) and the strict concavity of $U_i(\cdot)$, this only occurs if

$$\lim_{R_i \longrightarrow 0} \left[\frac{dU_i}{dR_i} - \lambda_i (p_R - p_d) - \eta_{R_i} a_R \right] \leqslant 0 \Longleftrightarrow \lim_{R_i \longrightarrow 0} \left[\frac{\frac{dU_i}{dR_i}}{\lambda_i} - (p_R - p_d) - \frac{\eta_{R_i}}{\lambda_i} a_R \right] \leqslant 0 \tag{18}$$

That is, if the marginal rate of substitution of recycling for money when R_i tends to zero is not sufficiently large to compensate the sum of the net unit cost of recycling and the minimum value of saving time from recycling. Even in the case of a high environmentally concerned individual for a purely altruistic individual ($\frac{\partial U_i}{\partial R_i}(\cdot) = \frac{\partial U_i}{\partial S_i}(\cdot) = 0$ and $\frac{\partial U_i}{\partial Q}(\cdot) > 0$), it can occur if the individual thinks that the impact of his/her personal recycling contribution has little effect on environmental quality. Conversely, in the case of a low environmentally concerned individual, the individual can decide to recycle if the warm-glow effect and the peer-approval effect have an important impact on his/her utility.

In summary, our theoretical model rests on the assumption, in line with empirical evidence, that recycling is not a leisure activity. It also rests on the assumption that individuals derive utility from recycling, as the counterpart to a warm-glow effect, an environmental concerns effect and a peer-approval effect. Given these assumptions, the model predicts that the value of saving time from recycling should increase with the actual level of recycling. Whether this prediction is empirically sound is examined in the following sections.

4 Combining a discrete choice experiment and a latent-class model

As stated, the value of saving time from recycling stems from time–money trade-offs. Typically, in a discrete choice experiment, respondents are asked to choose their most preferred option/alternative/scenario within a set of options/alternatives/scenarios, where alternatives are defined by attributes. Repeated choice tasks and/or ranking tasks allow collecting more information per individual.

Empirical trade-offs between attributes, for example between money and time attributes, are derived from the estimation of appropriate models on the data. Note that the value of travel time saving is commonly obtained by the estimation of discrete travel-choice models. For example, one of the first case studies given by Train (2009) to illustrate the logit model concerns the value of time in a model of work trip mode choice.

Thus, a discrete choice experiment on waste management should be an appropriate tool to assess the value of saving time from recycling, provided that the attributes defining the alternatives/options actually comprise time spent recycling and money attributes. From a methodological viewpoint, Larson and Shaikh (2001) establish that random utility models are suitable for empirical estimation of two-constraint (time constraint and budget constraint) theoretical models. Likewise, Jara-Díaz (2000) shows how a classical random (indirect) utility function can be derived from the theoretical model *à la* DeSerpa (1971).

Of course, an appropriate discrete choice experiment only provides data. The next step in estimating the value of (saving) time, *i.e.,* the value of transferring time from recycling to another activity, is to choose the appropriate technique from the econometric toolbox. Modeling the individual choice behavior heterogeneity can be achieved through a variety of models including the mixed logit model, the generalized multinomial logit model or the latent-class logit model (again, see Train (2009) for an outstanding presentation of discrete choice modeling approaches).

Recently, some leading authors (Hess *et al.*, 2011) convincingly argue that discrete mixture models (latent-class models) may have significant advantages over continuous mixture models. Notably, the choice of a discrete density function is less restrictive than the choice of a continuous density function to accommodate the heterogeneity in tastes across respondents.

In the basic behavioral model, the (indirect) utility that individual i obtains from choosing alternative j among J alternatives in choice situation t is

$U_{ijt} = \beta x_{ijt} + \epsilon_{ijt}$ where x_{ijt} is a k-vector of observed attributes of alternative j, β is a vector of coefficients (utility weights, homogeneous across individuals).

ϵ_{ijt} captures the factors that influence U_{ijt} but are not included in x_{ijt}.

The latent-class (logit) model assumes that there are C classes of taste/utility parameters $\beta = (\beta_1, \beta_2, ..., \beta_C)$.

Following the notations of Pacifica and Yoo (2013), if individual i is in class c, the probability of observing his/her sequence of choices (assuming each individual faces T choice situations) is

$P_i(\beta_c) = \prod_{t=1}^{T}\prod_{j=1}^{J}\left(\frac{\exp(\beta_c x_{ijt})}{\sum_{k=1}^{J}\exp(\beta_c x_{ikt})}\right)^{z_{ijt}}$ where $z_{ijt} = 1$ if individual i chooses alternative j in scenario t and 0 otherwise.

The class membership status is unknown and is usually specified as follows:

$\pi_{ci}(\theta) = \frac{\exp(\theta_c' y_i)}{1+\sum_{l=1}^{C-1}\exp(\theta_l' y_i)}$ where $\theta = (\theta_1, \theta_2, ..., \theta_{C-1})$ are class membership parameters, with $\theta_C = 0$ for identification (*i.e.,* class C is the reference class). The number of classes is chosen by the researcher on the basis of typical information criteria. After estimation, for example *via* the well-known Expectation Maximization algorithm (Pacifica and Yoo, 2013), willingness-to-pay estimates, and marginal rate of substitution (trade-offs) between attributes can be calculated for each class of individuals. Posterior probabilities, *i.e.,* probabilities that individual i belongs to class c given his/her sequence of choices, can also be predicted ($\widehat{\beta}$ and $\widehat{\theta}$ denoting the fitted parameters):

$\eta_{ci}(\widehat{\beta}, \widehat{\theta}) = \frac{\pi_{ci}(\widehat{\theta})P_i(\widehat{\beta}_c)}{\sum_{l=1}^{C}\pi_{li}(\widehat{\theta})P_i(\widehat{\beta}_l)}$.

5 Empirical analysis: solid waste management in Corsica

Corsica is a French island located in the Northern Mediterranean. It has a land area of 3,350 square miles and had a permanent population of 320,200 in 2013[3], making for a low population density of 95 inhabitants per square mile. Regarding solid waste services, 80% of the household solid waste was treated in 2010 in controlled landfills, some of which were non-standard and some of which reached a saturation threshold. In the same year, 19.3% of the household solid waste was sorted. The packaging recycling rate is less than 18%, which is much lower than the mean level for the whole of France (approximately 67%; PPGDNDC, 2013, p. 8). Due to the geographical constraints of its territory, its low population density and its low permanent population, no solid waste facilities (except for a few composting facilities) are present on the Corsican territory and recovered materials are sent to be treated on the French mainland. For sanitary reasons and to meet the requirements of European and French legislation, the Corsican Environment Agency (*Office de l'Environnement de la Corse*) in its Waste Management Plan (Piedma, 2002) decided to build an incinerator in a rural area in the center of Corsica. This incinerator project encountered strong opposition

[3]INSEE (French National Institute of Statistics and Economic Studies), General Census of Population 2013.

from an action group named "Against Corsican Incinerator" uniting various associations and representatives of civil society. The collective "Against Corsican Incinerator" based its opposition on the fact that this technological solution was both oversized and inadequate with regard to the size of the island's population and its geographical characteristics. The cost of the project and, mainly, the potential environmental and health impacts were also sources of the conflict. In light of the protest against the project, it was finally canceled on July 31, 2007, and no alternative solid waste management plan has been decided on to date. Therefore, significant efforts must be made in terms of recycling, and even more given the targets defined in the new Waste Management Plan for Corsica, which sets recycling rates much higher than the actual ones (over 45% of household solid waste and 75% of packaging waste; PPGDNDC, 2013, p.17) to meet the requirements of French legislation.

The need to understand local individual preferences regarding waste management options was at the core of the decision to conduct a specific survey on that question in 2008. Given the waste management issues faced in Corsica and the recent opposition to the incinerator technology, offering respondents the opportunity to express trade-offs between various waste management attributes seemed better than proposing a single scenario. As such, a choice experiment appeared to be a good candidate for the analysis we wanted to conduct.

As is typical in the choice experiment literature, choice attributes and their corresponding levels were derived from the literature on waste management, pretest studies and focus groups. We used a change in the current annual waste fee per household as a payment vehicle as it appears to be the natural extension of the actual tax payment for waste management services. The attributes and levels that were ultimately selected are presented in Table 1. Note that one of the attributes is the amount of time weekly spent recycling; combined with the cost attribute, this information allows us to assess the individual value of (saving) time from recycling.

Table 1: Attributes and their levels

Attribute	**Description**	**Levels**
FAC1	Categorical variable (1-5) coding the pollution impact (environmental degradation and health effects)	Degradation: Very High - High Intermediate - Low - Very Low
TIME	Categorical variable (1-5) coding time per week households spend on sorting and cleaning waste	More than 30 min. - 20 to 30 min. 10 to 20 min. - less than 10 min. - None
COST	Change in annual waste fee per household (€)	-40; -20; 0; +20; +40

Each of the levels taken by attribute $FAC1$ which codes the pollution impact, *i.e.,* the environmental and health effects, was precisely described to the respondents during the administration of the survey.

More specifically, the pollution impact attribute was presented from "Very Low" to "Very High" using an incremental formulation, as shown in Table 2, so that every respondent valued the same good.

Table 2: Description of attribute *FAC1*

Levels/Impacts	**Description**
Very Low	Mild noise or visual nuisances (*e.g.*, noise due to garbage trucks, visual pollution caused by plastic bags)
Low	Previous level (Very Low) + low impact pollution (no health effects)
Intermediate	Previous level (Low) + disturbing pollution
High	Previous level (Intermediate) + health impacts
Very High	Previous level (High) + heavy visual and odor nuisances

A large number of unique solid waste disposal technology service descriptions can be constructed from this number of attributes and levels. Given our 5^3 factorial structure, we constructed a design in 40 choice sets of 6 cards. Table 3 gives an example of a card.

Table 3: An example of a card

Situation 1		
Pollution impact	Time spent weekly on sorting and cleaning waste	Change in the annual waste fee
High degradation	more than 10 min.	-€20

The final survey was conducted face-to-face by six well-trained interviewers. They surveyed a representative sample of the Corsican population (481 respondents) in November and December 2008. The respondents were selected by stratified random sampling based on age, gender, population and location (INSEE, General Census of Population 1999). More details can be found in Beaumais *et al.* (2016).

Our survey asked each respondent to perform a full ranking task:

> **Ranking task:** Please rank the previous cards according to your preferences, with one (1) being most desirable and six (6) being least desirable

To analyze the data, we extend the basic latent-class logit model to the latent-class rank-ordered logit model, to make it suitable for rankings data. Typically a ranking of J alternatives is presented as a sequence of $J-1$ choice tasks: The alternative ranked first is chosen over all the other alternatives, the second ranked alternative is preferred to all others except the first ranked, etc. Thus, the latent-class rank-ordered logit model may be estimated *via* latent-class logit models over what Chapman and Staelin (1982) call the "exploded choice sets" or the "exploded choice observations": each individual i rank-ordered choice set can be decomposed (exploded) into $J_i - 1$ choice sets or choice observations used for estimation. As recommended by Daly and Hess (2011) the correlation across a given individual's choices is considered by estimating robust (sandwich) standard error estimators, clustered at the individual level.

As usual, the number of classes was chosen according to the BIC (Bayesian) and CAIC (Consistent Akaike) information criteria. The lower BIC and CAIC statistics were found for a 2-class model (2-LCROL). We also estimated a simple rank-ordered logit (ROL) model (one class) as a benchmark model. The results are reported in Table 4.

Table 4: ROL and 2-LCROL models

	Benchmark ROL		2-LCROL (Class 1)		2-LCROL (Class 2)	
Variable	**Coefficient** (standard-error)	**p-value**	**Coefficient** (standard-error)	**p-value**	**Coefficient** (standard-error)	**p-value**
Intercept						
FAC1_2[a] (high, β_{F2})	1.275	0.000	0	-	3.197	0.000
	(0.131)		(-)		(0.635)	
FAC1_3 (intermediate, β_{F3})	2.439	0.000	0	-	5.204	0.000
	(0.154)		(-)		(0.843)	
FAC1_4 (low, β_{F4})	3.332	0.000	1.453	0.000	6.230	0.000
	(0.165)		(0.107)		(0.869)	
FAC1_5 (very low, β_{F5})	4.111	0.000	1.453	0.000	7.260	0.000
	(0.172)		(0.107)		(0.869)	
TIME (η_R)[b]	-0.020	0.000	-0.013	0.041	-0.028	0.000
	(0.002)		(0.006)		(0.005)	
COST (λ)[c]	-0.021	0.000	-0.024	0.000	-0.028	0.000
	(0.001)		(0.003)		(0.003)	
Urban Dweller						
TIME	0.012	0.001	0.010	0.222	0.017	0.005
	(0.003)		(0.008)		(0.006)	
Class membership						
$\chi_i = (R_i - \overline{R})$, θ_χ	-	-	-0.031	0.015	ref. class	
			(0.012)			
Homeowner (1/0), θ_H	-	-	-0.528	0.061	ref. class	
			(0.281)			
Cst	-	-	-0.386	0.084	ref. class	
			(0.223)			
Cases	481		Cases	481		
LogLik	-2,205.59		LogLik	-2,150.24		
BIC	4,465.70		BIC	4,386.95		
CAIC	4,472.70		CAIC	4,400.95		

[a] Pollution impact (level) - reference category is 'Very High Degradation'
[b] Weekly time on sorting and cleaning waste, ten minute intervals
[c] Rise in annual waste fee per household

The class shares are approximately 34% and 66%. Individuals belonging to each class react to the cost attribute and the time attribute as expected. From a model of time allocation perspective, an increase in time spent recycling contributes to disutility *i.e.,* the marginal (indirect) utility of time spent recycling is negative. First, we estimated an unconstrained version of the model. However, class-one individuals were found to be less sensitive to the level of environmental degradation: They actually did not distinguish the various levels of environmental degradation, and only had a positive willingness-to-pay for low or very low degradation of the environment, compared to high degradation of the environment ($FAC1$ attribute, which is discretized). Thus, in the final version of the model, the class-one coefficients of the negative levels of $FAC1$ are constrained to zero, while the class-one coefficients associated with the positive levels of $FAC1$ are constrained to be equal. Note, however, that the unconstrained model better fits the data, according to the BIC and CAIC information criteria ($BIC = 4,334.34$, $CAIC = 4351.34$). Despite this finding, we favored the constrained version over the unconstrained version of the model because we considered the results from the unconstrained model to probably reveal non-attendance effects regarding $FAC1$ attribute.[4]

The class membership is influenced by two variables: The actual time spent recycling (in deviation from the mean, *i.e.* $R_i - \overline{R}$), and home-ownership status. The probability of belonging to class two increases with the actual time spent recycling, and individuals who own their home are also more likely to belong to this class. In fact, the data do not allow us to accurately disentangle the three effects of R_i as they are introduced in the theoretical model, namely the warm-glow effect, the environmental concerns effect and the peer-approval effect. Nevertheless, the three effects positively affect the utility. Therefore, we can consider the variable introduced in the class-allocation model (which is close to the definition of the peer-approval effect in the theoretical model) to actually capture the influence of a mix of these three effects. For each class c, the (indirect) utility function consistent with the estimated 2-LCROL can be written as follows (ignoring the interaction term between $TIME$ and urban status):

$$U_{ijt|c} = \beta_c x_{ijt} + \epsilon_{ijt} = \sum_{l=2}^{5} \beta_{Fl} \times FAC1\_l_{ijt} + \lambda c \times COST_{ijt} + \eta_R \times TIME_{ijt}$$

By definition, the value of saving time from recycling is the extra cost that an individual would be willing to incur to save time from recycling. Here, the total derivative with respect to changes in time and cost is:

$$dU_{ijt|c} = \lambda c \times dCOST_{ijt} + \eta_R \times dTIME_{ijt}$$

which we set equal to zero and solve for $\frac{dCOST_{ijt}}{dTIME_{ijt}}$ to find the change in cost that keeps utility unchanged for a change in time: $\frac{dCOST_{ijt}}{dTIME_{ijt}} \mid c = -\,\eta_R/\lambda c$. The value of saving time from recycling is therefore computed as a weighted sum of each class value for each individual, using the posterior probabilities as weights:

$$VSTR_i = -\sum_{c=1}^{2} \frac{\eta_{ci}(\widehat{\beta},\widehat{\theta}) \times \eta_R}{\lambda c}$$

Individual VSTRs vary according to the ratio $\eta_R/\lambda c$ and according to the actual time spent recycling (in deviation from mean, $\widehat{\theta}_\chi \times (R_i - \overline{R})$) and home-ownership status ($\widehat{\theta}_H$). To examine how VSTRs vary across classes, we then classify individual i as a member of class c if class c gives his/her highest posterior membership probability. The results are reported in Table 5.

As seen in Table 5, the value of saving time from recycling ranges from €4.38 to approximately €6

[4] To save space, results from the unconstrained model are not presented, but are available from the authors upon request.

Table 5: Value of saving time from recycling - €/h

	Mean	**Std**	**Min**	**Max**
Both classes	5.21	1.14	2.75	5.99
Class 1	3.18	0.46	2.75	4.33
Class 2	5.78	0.36	4.38	5.99

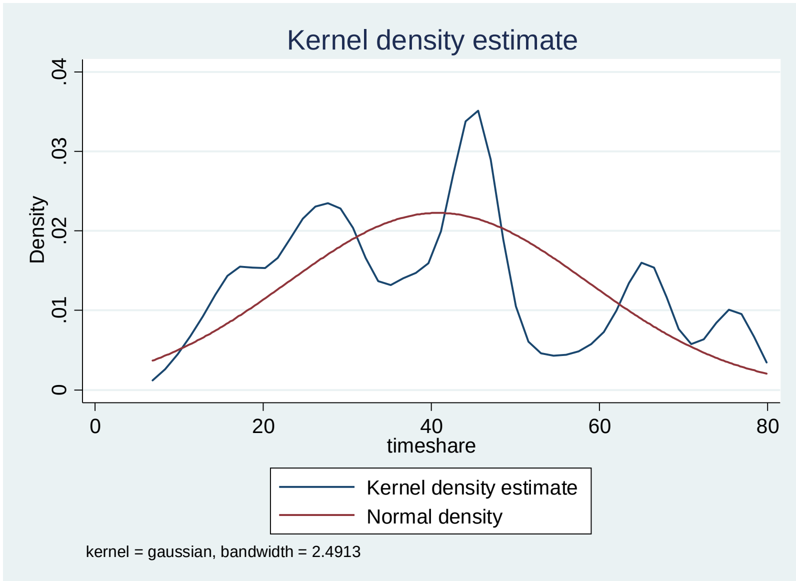

Figure 1: Kernel density estimate of the income share of the value of saving time from recycling

per hour[5] for class-two individuals, and from €2.75 to €4.33 for class-one individuals, showing significant heterogeneity. In terms of income share (Table 6), the value of saving time from recycling ranges from 13% to 76% for class-two individuals and from 8% to 53% for class-one individuals. This empirical result is in line with the predictions of the theoretical model. Indeed, the probability of belonging to class-two increases with the actual time spent recycling ($R_i - \overline{R}$) which in turn increases $VSTR_i$.

Table 6: Value of saving time from recycling - Share of the income

	Mean	**Std**	**Min**	**Max**
Both classes	41	18.23	8.38	75.73
Class 1	25.67	10.59	8.38	53.43
Class 2	45.48	17.55	12.57	75.73

Finally, the kernel density estimate of the income share of the value of saving time from recycling (Cf. Figure 1) exhibits high heterogeneity.

[5] Note that the $TIME$ variable was defined as 10-minutes intervals. Thus, to obtain estimates of $VSTR$ per hour, η_R is multiplied by six in the formulae presented in the text body.

6 Conclusions

Our results show that the value of saving time from recycling is highly heterogeneous across individuals. Clearly, researchers in the field of waste management should not assume a constant value for the opportunity cost of recycling. Ideally, numerous choice experiments such as ours could provide the required basis for a meta-analysis of the determinants of VSTRs. In the meantime, setting the opportunity cost of recycling equal to 40% of the average income could be acceptable. Additionally, we aknowledge that empirically disentangling the role of social norms, warm glow and other factors on household recycling would require specific questions that were not included in the 2008 survey.

In terms of policy implications, our results suggest that the waste collection point density and more generally waste infrastructures act as huge levers on recycling behavior, as they reduce the time required for a given output of recycling (a_R in our theoretical model). Finally, recycling is not a leisure activity, at least for the majority of the population. Still, evidence of positive preference for individual recycling efforts is rare in the literature (see Czajkowski *et al.* (2014)). Latent-class models should help examine further whether, at least for part of the population, recycling is not a waste of time.

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