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Cantillo, T, Notaro, S, Bonini, N et al. (1 more author) (2023) Assessing Italian household preferences for waste sorting systems: The role of environmental awareness, socioeconomic characteristics, and local contexts. Waste Management, 163. pp. 22-23. ISSN 0956-053X

https://doi.org/10.1016/j.wasman.2023.03.014

Household's preferences for waste sorting systems: The role of values, socioeconomic characteristics, and contexts

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Abstract: Efficient Waste Management Systems (WMS) depend on citizens' willingness to sort waste and to cooperate for its improved provision. Thus, it is essential to understand what attributes individuals valuate the most and what drives WMS preference heterogeneity. In this paper we investigate how individuals valuate WMS attributes (e.g., the number of waste sorting categories, the introduction of textile sorting, and frequency of collection per week) and how the local contexts, socioeconomics and environmental values shape their preferences. We collected data from a representative Italian sample and analysed them using hybrid mixed discrete choice models. We found that individuals are willing to pay for an improved WMS, even if this implies an increased effort, from their part, and storage space. In addition, we found that the extent to which individuals support WMS improvements strongly depends on their environmental values, experiences (shaped through their local context) and socioeconomic factors. Our results suggest that to increase recycling rates and citizen satisfaction, there is a need for context-specific WMS designs that acknowledge the observed heterogeneity of preferences.

Keywords: Waste sorting systems, Circular Economy, willingness to pay (WTP), hybrid choice models

1. Introduction

A circular economy is increasingly seen as a pillar for achieving Global Sustainability Goals. Several governmental bodies, including the European Union, are putting strong circular economy targets at the top of their policy agenda (Camana et al., 2021). To achieve these goals, we need a waste management system (WMS) that efficiently recovers garbage from the source to treatment facilities and, thus, a system in which end consumers recycle their waste (Di Foggia and Beccarello, 2021). Thus, the individuals' willingness to sort waste constitutes a key pillar for an efficient WMS. Therefore, understanding people's preferences, and thus, willingness to participate in the provision of this quasi-public good, is essential for the success of a circular economy.

Because waste sorting is a time, space and effort consuming activity, households' motivation for cooperating with the WMS has been widely studied in the literature (Berglund, 2006; Gilli et al., 2018; Czajkowski et al., 2019; Aprile and Fiorillo, 2019). It has been found that social norms, personal values, environmental contexts, and demographics are among the main drivers of individuals' willingness to recycle (Degli Antoni and Vitucci Marzetti, 2019; D'Amato, 2016; Vassanadumrongdee and Kittipongvises, 2018). Moreover, recent literature argues that economic incentives play a small role in recycling when compared to individual and social norms and values (Berglund, 2006; Degli Antoni and Vitucci Marzetti, 2019). Consequently, understanding how values and socioeconomics shape a households' willingness to contribute to WMS is essential to its efficient design.

Using Italy as a case study, in this paper, we uncover how environmental values, socioeconomic and local factors shape the willingness to cooperate for an improved WMS by examining households' stated willingness to pay (WTP) for improved WMS attributes. We use a hybrid mixed logit to disentangle the impact of socioeconomics on waste sorting through its impact on environmental values and through its impact on other specific traits of the demographic group. In addition, we analyze how the local recycling rate, population density, and type of collection system, which are factors that impact a household's environment, shape the preferences for an improved WMS. To the best of our knowledge, this issue has not been empirically studied in the literature.

Italy constitutes an interesting case study as the recycling rate varies widely across regions, with high recycling rates (around 71%) in the north and medium-low rates in the south (around 54%)[1]. As in Italy the WMS is managed at the local level, this heterogeneity has been linked to differences in the economic and social development across regions, which in turn translates to a lower capacity to secure collection and treatment of waste (Cerqueti et al., 2021; Di Foggia and Beccarello, 2021; Lombardi et al., 2021; Chakraborty et al., 2022; Romano et al., 2022). Our study analyses the attributes households living in low- and high-recycling rate municipalities value the most.

In sum, our research contributes to the stream of literature on efficient WMS designs as it allows to disentangle the main factors affecting the heterogeneity of households' preferences for improved WMS designs. Therefore, considering different contexts and socioeconomics, our results give important insights to policymakers on how to increase households' wellbeing and willingness to recycle.

The rest of the paper is organized as follows. Section 2 reviews households' willingness to pay for improved WMS and their motivations to recycle. Section 3 introduces the data and experimental design used in this study. Section 4 presents the methodology used. Section 5 presents the results, whilst section 6 discusses them. Finally, section 7 concludes.

2. Literature review

Stated preference (SP) surveys have received increasing attention in recent years as a method to understand households' intention to recycle and cooperate for WMS improvements, due to their low costs and simplicity compared to randomised control trials (Czajkowski et al., 2019). Examples

[1] Statistics obtained for the Superior Institute for Environmental Protection and Research available at: https://www.catasto-rifiuti.isprambiente.it/index.php?pg=nazione

include Ferreira and Cuhna Marques (2015), Song et al. (2019), Vassanadumrongdee and Kittipongvises (2018), and Kayamo (2020), who used contingent valuation methods (CVM) to understand households' willingness to pay for the introduction of waste recycling in Portugal, Bangladesh, Thailand and Ethiopia, respectively.

Discrete choice experiments (DCE) have gained popularity within SP methods in estimating preferences for WMS improvements. Unlike other SP approaches, DCE allows valuating multiple attributes and calculating the trade-offs between them. Overall, besides costs, the most popular WMS attributes valuated in the literature are the collection frequency and the number of waste-sorting categories (Karousakis and Birol, 2008; Czajkowski et al., 2014, Benyam et al., 2020). In general, higher collection frequency has been linked to higher WTP levels, whilst mixed results have been found with respect to the number of sorting categories.

Because waste-sorting behaviour does not seem to follow an economic logic, recent literature has studied the main factors influencing willingness to cooperate on recycling. For example, studies have addressed the role of certain demographic characteristics on recycling intention and behavior, such as age, gender, education level, income, and household characteristics (Vassanadumrongdee and Kittipongvises, 2019; Benyam et al., 2020; Romano et al., 2022). However, the impact of demographics on willingness to sort waste has received mixed results and, in general, was found to have a small impact when compared to psychological and institutional factors such as values and attitudes (Aprile and Fiorillo, 2019; Romano et al 2022).

Overall, the main psychological factors influencing willingness to recycle include habits, attitudes, perceptions, values, and social and subjective norms (Massarutto et al., 2019, Czajkowskia et al., 2019, Agovino et al., 2019; Degli Antoni and Marzetti, 2019). Examples of such factors include environmental values, trust, peer-pressure, perceived environmental benefits and social rewards. Considering the importance of psychological factors on recycling behaviour, a stream of research has aimed to include these factors in estimations of recycling intention. Some studies have directly used indicators of these unobservable psychological factors to measure their impact. For example, Aprile and Fiorillo (2019) used indicators of environmental concerns to empirically measure their impact on recycling behaviour in Italy. Others have measured these psychological factors using more sophisticated factor analysis techniques. For instance, Vassanadumrongdee and Kittipongvises (2019) used factor analysis to estimate the influence of latent traits such as perception of inconvenience, pro-environmental attitudes, and subjective norms towards waste-sorting on WTP estimates for WSM improvement, finding significant and strong impacts. In addition, latent class models (LCM) have also been used for this purpose; examples include Massarutto et al. (2019) and Nainggolan et al. (2019). Nevertheless, LCM, though useful, is disadvantageous in relying too much on the researchers' intuition about the drivers of the observed class heterogeneity (Weller et al., 2020).

In conclusion, although the individuals' willingness to cooperate for an improved WMS has been systematically assessed in the literature, a gap remains in understanding the role of local contexts in shaping those preferences. In addition, to the best of our knowledge, previous research on the impact of socioeconomics on WMS preferences has not analyzed whether socioeconomics exert an influence through their association with environmental values or through their association with some other traits common to the demographic group. The present work aims to fill these gaps. Finally, to measure environmental awareness values we use the hybrid modelling technique, which despite having been recognized as a robust method to include latent traits in WTP estimates (Ben-Akiva et. Al, 2002), its use has been very limited in the literature on WMS preferences.

3. Data and experimental design

Our research is built upon a national stated preference survey of Italian households carried out online in April 2020 with the support of a professional market research company specialized in opinion surveys. Because the contract with the market research company contemplated all questionnaires compiled, there is a null non-response rate. We collected 605 questionnaires. After cleaning the data by removing protesters, we analyzed the data of 547 respondents from 272 municipalities.

The survey was developed based on widely-accepted guidelines for DCE (Riera et al. 2012; Johnston et al. 2017) and it was comprised of three parts. In the first section, we collected information on the WMS. In the second section, we described the attributes and levels of the DCM. Subsequently, we presented 12 choice situations. In the final section we collected attitudinal indicators of pro-environmental values and socio-demographic characteristics.

In Italy, WMS is managed at the local level (municipality). In all regions, households pay a municipal waste management tariff (TARI[2]) which comprises fixed costs (determined based on the costs of the service, i.e., investments and depreciations) and variable costs (to finance waste transport, collection recycling, and disposal) related to the amount of waste produced. For households, the TARI is calculated considering the surface of the house and the family size. In some municipalities, the quantity of residual waste produced and recycled is also considered. Each municipality sets the TARI with respect to the quantity and quality of waste produced. Thus, municipalities with a higher average TARI tend to have lower recycling rates (Confcommercio, 2022; Lombardi et al., 2021). This was reflected in our data, as a significant negative correlation was found between the municipal recycling rate and the TARI paid[3].

Table 1 portrays the descriptive statistics from the respondents in our sample and from their municipality, including general contextual variables (recycling rate and population density) and attributes of the WMS (TARI paid in 2020, type and frequency of collection), compared with the Italian census data, when applicable. In terms of WMS attributes, the average TARI paid in 2020 by

[2] In Italian *Tassa sui rifiuti*.

[3] The correlation size was -0.17, the Pearson's product moment correlation coefficient was -4.05.

sample's respondents was 274€, but the exact amount varied widely across respondents as the standard deviation was 147€. In terms of socioeconomics, our sample was representative of the Italian population with the exception that it was slightly more educated.

Table 1: Socio-demographic characteristics of respondents compared to Italian population, WMS attributes and context-specific variables

	Variable	Sample range/Categories	Sample distribution			Italian population
			N	Mean	s.d.	Mean
Sociodemographic	Gender (Categorical)	0 if Male	284	0.520		0.482
		1 if Female	263	0.480		0.518
	Age (continuous)	Age in years. 18 years lower limit, 65 years higher limit		43.40	12.2	
		18-24 years		0.084		0.082
		25-34 years		0.188		0.127
		35-44 years		0.221		0.154
		45-54 years		0.269		0.192
		55-64 years		0.223		0.166
		> 65 years		0.015		0.276
	Bachelor (Categorical)	0 if educational attainment is high-school or lower	323	0.590		0.821
		1 if educational attainment is bachelor's degree or higher	224	0.410		0.179
	Household size (Categorical)	0 if household size is lower than 3 family members	100	0.182		0.58
		1 if household size is equal or higher than 3 family members	449	0.820		0.41
	Income (Categorical)	0 if annual income after tax is lower than 40,000 EUR	490	0.896		0.923
		1 if annual income after tax is higher or equal than 40,000 EUR	57	0.104		0.077
	Political orientation (Categorical)	0 if center or right	344	0.629		
		1 if left	203	0.371		
WMS attributes	Actual Collection Frequency (continuous)	1 time per week	67	0.122		
		2 times per week	121	0.221		
		3 times per week	101	0.185		
		4 times per week	37	0.068		
		5 times per week	66	0.121		
		6 times per week	109	0.199		
		7 times per week	46	0.084		
	Type of Collection (Categorical)	0 if collection type is door-to-door or mixed collection	299	0.547		
		1 if collection type is curbside collection	248	0.453		
	TARI (Continuous)	TARI paid 2020. 30 euros lower limit, 1,000 euros higher limit		274	147	
Context specific variables	Recycling rate (continuous)	Proportion of waste recycled in 2020 per municipality. 10% lower limit, 87% higher limit (ISPRA, 2020)		56%	17%	
	Population density (continuous)	1000 habitants per Km^2 in municipality. 0.1 lower limit, 12.1 higher limit (ISTAT, 2022)		2.41	2.26	

Notes: Source of descriptive statistics for Italian population: Istituto Nazionale di Statistica (2020)

Following a review of the literature and after performing a focus group with participants recruited from the general population, we included four attributes in our choice modeling experiment:

additional waste sorting categories, the introduction of textile sorting[4], frequency of collection per week, and costs in the form of a percentual increase in the TARI. A summary of attributes and levels, which were also selected based on the literature and focus group discussion, is presented in table 2. Following purely utilitarian views, there is no rationale for individuals to positively evaluate the first two attributes, i.e., additional waste-sorting categories and the introduction of textile collection, as they both imply an increase in effort, time, and space. Thus, for these variables, it is key to understand how non-utilitarian factors influence the willingness to pay and engage in recycling. In this investigation, we focused on environmental values as the rationale for sorting waste is linked to environmental sustainability targets.

Table 2: Attributes and levels of experiment

Attribute	Description	Levels
Categories of waste	Number of additional waste sorting categories	***No more categories*** ***+1***: 1 additional category ***+2***: 2 additional categories
Textile collection	Introduction of textile collection	***Yes*** ***No***
Collection frequency	Number of times per week the collection of one or more categories of waste is carried out	***3 times*** ***5 times*** ***7 times***
Costs	Percentage increase of the annual waste management tariff (TARI)	***+ 3%*** : increase by 3% ***+ 5%*** : increase by 5% ***+ 7%*** : increase by 7% ***+ 10%*** :increase by 10%

To measure environmental attitudes, we used the New Ecological Paradigm (NEP) scale (Dunlap et al., 2000). The construct validity of NEP has been widely tested with positive results, making it one of the most popular measures of environmental values and attitudes (Matsiori et al., 2020). Lately, it has also been used to estimate the impact of pro-environmental attitudes on WTP estimates (see Tyllianakis and Ferrini (2021), Bartczak (2015), and Faccioli et al. (2020), among others). The revised NEP scale consists of 15 items and uses a 5-point Likert response scale (see table A.1 in the

[4] At the time of the research, in Italy textile materials were thrown into undifferentiated waste; they were not recycled. As of January 1 2022, through legislative decree 116/2020, the obligation to separate textile waste came into effect, put forward by three years the implementation of one of the decrees contained in the "Package of directives on the circular economy" adopted by the European Union in 2018. However, the entire supply chain is still not truly operational and functional.

appendix). After performing exploratory factor analysis, item 6 of the revised NEP was deleted from our study as it did not provide a significant loading to the latent construct in our sample (see table A.2 in appendix).

Finally, an efficient design (Rose and Bliemer, 2009) generated with Ngene software (ChoiceMetrics, 2018), was used to generate the 12 choice situations. The priors were obtained through a pilot survey involving 100 respondents. The design of the pilot was also made through an efficient design, using priors from the literature. In addition, although cost levels were presented as a percentual increase of the TARI, we also calculated a family estimate of the value in euros and presented it in the choice cards alongside the percentage increase. An example of the choice card is portrayed in figure 1.

Figure 1: Example of choice card for respondents that paid a TARI equal to 200 EUR in 2020

Please indicate whether you prefer system A or system B, or neither.			
	System A	**System B**	**Neither**
Categories of waste	No more categories	+2	I prefer the current WMS
Collection of textile waste	No	Yes	
Collection frequency	7 times	5 times	
Costs	7% (14 EUR)	3% (6 EUR)	
I CHOOSE:	○	○	○

4. Methodology

Our methodological approach is built upon the use of hybrid choice models, which have gained increasing recognition for assessing the impact of latent variables (LVs) in WTP estimates such as attitudes, perceptions, and values (Walker, 2001). Hybrid models allow to estimate and include LVs in the utility function, and thus to compute their impact on WTP values. In addition, they are considered superior to two-step factor analytical approaches, as they simultaneously estimate the LVs and the coefficients of the utility function, avoiding endogeneity and omitted-variable biases (Vij and Walker, 2016). Futhermore, the LVs are estimated using a multiple causes and indicators (MIMIC) approach, which allows uncovering how socioeconomic and other observable variables shape LVs. Therefore, the MIMIC approach generates a valuable framework for making predictions.

Hybrid choice models comprise three components. The first is the discrete choice part, which models individual's utility based on the random utility theory (Walker, 2001). The second and third are the measurement and structural equations of the MIMIC framework, which model the LVs. Below we explain in detail each of these components in the context of our case study.

4.1. Discrete choice model

Following the random utility theory, the utility that an individual i obtains for the proposed changes on the WMS j and the status quo s in each choice situation k can be modelled as:

$$U_{ijk} = \theta c_{jk} + \beta X_{jk} + \alpha EA_i X_{jk} + \delta S_i X_{jk} + \varepsilon_{ijk} + \epsilon_i \quad (1)$$

$$U_{isk} = \theta c_{sk} + \beta X_{sk} + \alpha EA_i X_{sk} + \delta S_i X_{sk} + \varepsilon_{isk} + \gamma_i$$

Where c_{jk} and c_{sk} are the costs of the proposed improvements in the WMS and of the status, thus θ is the marginal utility of income. X_{jk} and X_{sk} are vectors of the attributes of the alternatives (i.e., frequency of collection, introduction of textile sorting, and additional sorting categories). β is the vector of baseline coefficients of the WMS attributes X. EA_i is the latent variable *environmental awareness* (EA) measured via the NEP scale, thus α is a vector of coefficients measuring EA's impact on the preferences for WMS's attributes X. Similarly, S_i is a vector of socioeconomics and contextual characteristics of the individuals, and δ is a vector of coefficients measuring the impact of demographics and the surroundings on the preferences for X. ε_{isk} are independent but identically distributed (IID) Gumbel error components reflecting all unobservable idiosyncratic factors influencing individual's preferences. Finally, ϵ_i and γ_i are error terms $N(0, \sigma^2_{panel})$ with a twofold function. First, ϵ_i and γ_i capture the correlation effect among observations of the same individual, so called pseudo-panel effect (Hess et al., 2008; Cantillo et al., 2007). Secondly, ϵ_i and γ_i capture the correlation of the alternatives proposing a change in the WMS $j = (1,2)$, thus relaxing the assumption of Independence from Irrelevant Alternatives (IIA) (Walker, 2001).

We estimate a random parameters logit in WTP space[5] (Train and Weeks, 2005) to capture unobserved preference heterogeneity. We propose a negative log-normal distribution for the cost coefficient $\theta\ -Lognormal(\mu_\theta, \sigma_\theta^2)$ and a normal distribution for the baseline coefficients β $N(\mu_\beta, \sigma_\beta^2)$, whilst the interaction coefficients (α and δ) are considered constant.

4.2. MIMIC framework: structural and measurement equations

The latent variable EA is measured following the MIMIC approach, composed of measurement and structural equations. The measurement equations relate the weight that the latent variable EA has in explaining the observable NEP indicators (NEP_{ir}), specifically it portrays that each indicator r can be explained by the latent variable EA_i:

$$NEP_{ir} = \gamma_r EA_i + e_{ir} \tag{2}$$

Where γ_r reflects the degree in which the latent variable EA_i explains each of the observable r NEP indicators. e_{ir} is an error term following a normal distribution. As the NEP indicators are measured with a 5-point Likert scale, equation (2) is estimated using an ordered regression.

On the other hand, the structural equation measures the influence of different observable variables such as socioeconomics characteristics on the latent variable EA:

$$EA_i = \eta S_i + \xi_i \tag{3}$$

Where η is a vector measuring the impact of each observable variable S_i on EA_i, whilst ξ_i is an error term following a normal distribution. Through (3) we can, therefore, measure the impact of demographics and contextual variables S_i on individual's environmental attitudes. Therefore, to estimate the overall impact of S_i on the preferences for each WMS's attribute X, we need to

[5] To get estimations in WTP space we multiply equation (1) by the cost coefficient.

consider both its direct impact, through δ in (1), and its indirect impact, through η in (3) and α in (1).

Equations 1-3 are estimated using simulated maximum likelihood method (Walker, 2002). We used the package APOLLO in R (Hess and Palma, 2019). One thousand random Halton draws were used in the estimations.

5. Results

To understand the average preferences in our case-study, we first estimate random-parameters logit without interaction effects. The results are portrayed in table 3. In line with previous investigations (i.e., Czajkowski et al., 2014; Massarutto et al., 2019; Benyam et al., 2020), a higher frequency of waste collection is positively valuated by respondents. In our case, individuals are, on average, willing to pay 1.08€ to increase the weekly frequency of collection by one day. Our results also show that respondents have an average WTP of 3.68€ and 3.77€ to increase, respectively, by one and two the number of sorting categories. In addition, the introduction of textile collection is the attribute that individuals, on average, valuate the most, with a WTP of 6.54€. The positive valuation of extra waste-sorting categories and of textile collection supports the thesis that non-utilitarian factors play a key role in explaining WTP estimates concerning WMS improvements. On the other hand, our results show that, on average, respondents hold lower preferences from the status quo.

Concerning preference heterogeneity, the high unobserved heterogeneity of textile sorting and frequency of collection is noteworthy, with a standard deviation of 7.77€ and 3.58€, respectively. In contrast, the standard deviation of the addition of one or two sorting categories is lower and less significant. Interestingly, the attribute that was absent in the Italian WMS when the survey was collected, i.e., textile collection, had the highest preference heterogeneity. We believe that this may be caused by the lack of experience of individuals towardthis attribute, causing skepticism or over-excitement on its environmental benefits and feasibility.

Table 3: Random parameters logit results in WTP space

Attribute	Mean coefficients	Standard deviations
ASC status quo	-3.34***	3.85***
	(0.63)	(0.14)
+1 category	3.68***	0.59
	(0.52)	(0.37)
+2 category	3.77***	1.36**
	(0.51)	(0.55)
Textile collection	6.54***	7.77***
	(0.49)	(0.68)
Frequency	1.08***	3.58***
	(0.16)	(0.27)
Costs	-2.43***	1.60***
	(0.15)	(0.08)
Pseudo-panel		3.17***
		(0.2)
Number of individuals	547	
Number of observations	6564	
Log-likelihood	-4,642.46	
AIC	9310.93	
BIC	9399.19	
McFadden's R2	0.34	

Notes: Standard deviations in parenthesis
** and *** indicate significance levels at 5% and 1%, respectively

Although the results in table 3 display the overall picture of WMS's preferences, they do not address the cause of the heterogeneity of preferences for WMS's attributes, nor to what extent context-specific and socioeconomic variables are influencing WTP estimates. For this purpose, we estimated a hybrid random-parameters logit with interaction effects (see equations 1-3). Results for the discrete choice component are portrayed in table 4 and for the MIMIC component in table 5. The description of the covariates can be found in table 1. It is worth mentioning that the covariates *Population density* and *Recycling rate* were centered at zero to avoid any spurious impact on the alternative specific constant.

Table 4 shows that the Environmental Awareness (EA) construct measured with the NEP scale has a significant and positive impact on WTP for improvements in WMS. In particular, individuals with high EA positively valuate increases in sorting categories. The marginal impact of EA on the WTP for 1 and 2 additional categories are 0.8€ and 1.5€, respectively. Textile sorting is the attribute that high EA individuals value the most, with a marginal WTP of 2.43€. Finally, regarding the frequency of collection, WTP also increases with EA values, with a marginal WTP of 0.45€.

We now turn to table 5 to understand the impact of demographics on EA values. Curbside collection was not included as a predictor of EA, as theoretically there should not be a link between this covariate and EA. Consistent with the literature (Dunlap, 2000), we found significant evidence suggesting that female and political left-wing individuals have higher EA. In addition, in our case study, older and higher-income individuals have higher EA values.

Our results also suggest that individuals living in high recycling rate municipalities develop higher EA values. We recognize that there may be simultaneity in the causality of this relationship as individuals with higher EA values may also tend to recycle more. Nevertheless, as we use municipality data, we can assume that this variable is exogenous to the individual. In contrast, although not significant, individuals living in high population density cities with a household size equal to or bigger than 3 have higher EA values. Finally, an unexpected, though not significant, result emerges from the negative correlation of a bachelor's degree in the construct EA.

We turn back to the discrete choice estimates (table 4) to understand the impact of socio-demographics and environmental (context-specific) variables on WTP estimates. In doing so, it is important to bear in mind that these variables have a two-way impact on preferences: 1) There is an indirect impact through their influence on EA values, 2) there is a direct impact capturing other traits specific-to the demographic group. These direct and indirect values are calculated and portrayed in table A.3 of the appendix section.

In general, we find that the indirect impact of demographics on WMS preferences is lower than their direct impact. Therefore, our results portray that, in most cases, the influence of socio-demographic characteristics on WMS preferences through EA values is low when compared to other traits specific to the group. This result is in line with Pienaar et al. (2013), who found that the relationship between socio-demographics and environmental values, measured by the NEP scale, is weak.

Nevertheless, we find strong evidence suggesting that socio-demographics and context-specific variables shape individuals' preferences for WMS attributes. Focusing on direct estimates (table 4 coefficients), we find that, despite having higher EA values, women and older individuals are less eager to increase household waste sorting categories. In addition, families with three or more members and high-income households have a higher willingness to pay for increasing waste sorting categories.

Our results also demonstrate that textile collection is less valuated by bigger households and individuals from left-wing parties. However, it is important to bear in mind that these individuals also report higher EA values. In fact, for left-wing individuals, the positive indirect impact on WTP for textile collection through EA is almost as high as its negative direct impact. On the other hand, turning to the frequency of collection, we find that high income and left-wing individuals, who also have higher EA values, have higher preferences for this attribute.

An unexpected result arises from the lower WTP estimates of extra sorting categories and textile introduction from individuals with a bachelor's degree compared to their counterparts. Nevertheless, despite having an overall lower WTP for WMS attributes, individuals with a university degree have higher WTP to change from the status quo situation.

Turning to the local context variables *Curbside collection*, *Population density* and *Recycling rate,* we find that they have an important influence in shaping preferences for WMS improvements. In particular, individuals with a curbside collection scheme have lower willingness to increase their waste sorting categories and introduce textile collection in comparison to individuals with a door-to-door collection scheme. On the other hand, the willingness to change the WMS with respect to the status quo is lower for individuals with a curbside collection scheme.

Population density and recycling rate are significant predictors of preferences for textile collection and frequency of collection, partly explaining the significant heterogeneity of these attributes (measured by the standard deviation). First, we find that an increase in the recycling rate by 1% and by 1000 habitants per Km^2 in the population density, decrease WTP for a more frequent WMS by 0.27€ and 0.02€, respectively. Second, our results also show that individuals living in more densely populated areas and with lower recycling rate have higher WTP for the introduction of textile sorting. A decrease in the recycling rate by 1% and an increase of population density by 1000 habitants per Km^2 increases WTP for textile introduction by 0.08€ and 0.41€, respectively.

Finally, we also find the standard deviation of our baseline estimates slightly decreases, portraying that some of the heterogeneity of preferences is captured by the analysis of covariates, i.e., values, socioeconomics, and the local context.

Table 4: Discrete choice estimates of hybrid mixed logit results in WTP space with all interactions

Attributes	Means	Standard deviations	Interactions									
			LV	Socioeconomic demographics						Local contexts		
			NEP	Female	Household size	Age	Bachelor	Political left	High Income	Population density	Recycling rate	Curbside collection
ASC status quo	10.18***	1.78**	-0.22	-3.87***	1.66	-0.10*	-5.19***	0.19	1.44	0.02	0.01	-5.21***
	(3.39)	(0.69)	(0.67)	(1.27)	(1.49)	(0.06)	(1.21)	(1.02)	(1.60)	(0.29)	(0.06)	(1.07)
+1 category	5.07	0.82***	0.80**	-3.26***	3.02**	-0.03	-2.3**	1.96	1.01	0.39	-0.03	-1.52*
	(3.32)	(0.20)	(0.39)	(0.95)	(1.19)	(0.06)	(1.06)	(1.20)	(1.18)	(0.24)	(0.03)	(0.79)
+2 category	9.12***	2.92***	1.50***	-1.45*	1.71	-0.14**	-3.36***	0.65	2.25*	0.22	0.01	-1.62*
	(3.2)	(0.68)	(0.50)	(0.88)	(1.28)	(0.05)	(1.17)	(1.06)	(1.32)	(0.25)	(0.04)	(0.9)
Textile collection	10.81***	5.79***	2.43***	-0.99	-1.45*	0.03	-5.16***	-1.59**	-0.51	0.41**	-0.08**	-3.30***
	(2.52)	(0.49)	(0.30)	(1.02)	(0.83)	(0.04)	(0.89)	(0.66)	(1.2)	(0.18)	(0.04)	(0.81)
Frequency	-0.51	2.24***	0.45***	0.08	0.01	0.01	-0.07	1.08***	1.01***	-0.27***	-0.02***	0.01
	(0.66)	(0.28)	(0.11)	(0.26)	(0.01)	(0.01)	(0.27)	(0.17)	(0.38)	(0.04)	(0.01)	(0.20)
Costs	-2.71***	1.81***										
	(0.14)	(0.14)										
Pseudo-panel		3.41***										
		(0.24)										
Number of individuals	547											
Number of observations	6564											
Log-likelihood (Whole model)	-13260.55											
Log-likelihood (Choice component)	-4608.97											
McFadden's R2 (Choice component)	0.35											

Notes: Standard deviations in parenthesis
*, ** and *** indicate significance levels at 10%, 5% and 1%, respectively
Recycling rate and population density were centered to zero

Table 5: MIMIC coefficients of hybrid mixed logit results in WTP space with all interactions

Measurement equations		Structural equations	
NEP 1	0.43*** (0.10)	Female	0.22*** (0.10)
NEP 2 (r)	1.44*** (0.13)	Age	0.02*** (0.00)
NEP 3	1.92*** (0.20)	Recycling rate	0.01* (0.00)
NEP 4 (r)	0.38*** (0.10)	Population density	0.03 (0.02)
NEP 5	3.01*** (0.33)	Household size	0.16 (0.13)
NEP 7	1.71*** (0.16)	Bachelor	-0.10 (0.09)
NEP 8 (r)	1.60*** (0.15)	High Income	0.34** (0.17)
NEP 9	1.08*** (0.13)	Political orientation	0.45*** (0.09)
NEP 10 (r)	1.29*** (0.13)		
NEP 11	0.91*** (0.12)		
NEP 12 (r)	1.61*** (0.15)		
NEP 13	1.88*** (0.19)		
NEP 14 (r)	1.21*** (0.13)		
NEP 15	2.93*** (0.31)		

Notes: Standard deviation in parenthesis
*, ** and *** indicate significance levels at 10%, 5% and 1%, respectively
(r) indicates that the scale has been reversed

6. Discussion

Our study highlights the importance of non-utilitarian factors and social contexts in shaping citizens' preferences for WMS, thus supporting previous research on the motivations of recycling behaviour (Massarutto et al., 2019; Czajkowski et al., 2019). Nevertheless, by analysing how the local environment and environmental awareness shape individuals' willingness to cooperate for an improved WMS, our research makes a significant departure from the current stream of literature.

We found a significant impact of local contexts (curbside collection, recycling rate, and population rate) on individuals' WTP for WMS attributes, highlighting the importance of experiences and local context in shaping preferences. First, we found that individuals with a curbside collection scheme value less the introduction of extra-sorting categories and textile collection than those with a door-to-door collection scheme. In a curbside scheme, the collection point is further away from the household, thus the introduction of more categories involves extra-effort. Therefore, the collection scheme and number of categories should be assessed jointly on WMS designs, as they interact with individuals' utility. In addition, we also found that individuals with a curbside collection scheme have a higher willingness to change the WMS with respect to the status quo, thus, probably signaling dissatisfaction with the service. In fact, Lombardi et al. (2020) found that introducing a door-to-door collection scheme was linked to a higher recycling rate in Italian municipalities.

Another relevant finding arises from the interaction of the recycling rate with the studied WMS attributes. We found that individuals living in low recycling rate municipalities have higher WTP for increasing the frequency of waste collection and introducing textile sorting. This shows citizens' willingness to cooperate to increase the recycling rate at low-efficiency levels. Therefore, our results demonstrate that low-recycling rate municipalities should focus on improving frequency of waste collection. This strategy increases overall recycling efficiency and household satisfaction with the system.

Finally, we also found that population density is an important predictor of WTP for WMS attributes; individuals living in municipalities with low population density have higher preferences for a more frequent collection system. This is coherent with the literature, which evidences that individuals living in rural areas have higher nature-relatedness values (Bashan et al., 2021) and, thus, higher preferences for sustaining a cleaner environment near their households. In contrast, our results also report that the introduction of textile collection, an attribute which was not present in the Italian

WMS when the study was conducted, is more valuated by citizens living in denser municipalities. As the introduction of textile collection in Italy would constitute an innovative WSM policy, our results are consistent with the evidence reporting that individuals living in more dense cities have a higher willingness to implement transformative and novel policies and ideas (Florida et al., 2017; Kunkel et al., 2022).

We also evaluate how socioeconomics impact WMS preferences by analysing the magnitude and direction of its indirect impact through its influence on environmental values, its direct impact, and other demographic-specific characteristics. We found that socioeconomics is a relevant predictor of WTP for WMS attributes, as previously analysed in the literature (Romano et al., 2022). Moreover, we found that its indirect impact through environmental values is low when compared to its direct one, which captures other demographic-specific traits influencing decisions. Further investigation is needed to uncover how socioeconomics impact WMS preference directly.

Finally, as environmental awareness values are a significant predictor of WTP estimates, improvements in WMS should be accompanied by public campaigns aimed at increasing awareness of its environmental benefits. Higher environmental awareness will lead to higher support of households for an improved WMS and, thus, increase overall wellbeing through a higher recycling rate and satisfaction with the system.

We have uncovered how local contexts, environmental values, and demographics influence preferences for WMS. Understanding the drivers of WMS preference heterogeneity is key for assessing the wellbeing and distributional impacts of any WMS policy. Therefore, our results are very relevant to effectively improve citizens' welfare and increase the WMS's efficiency.

7. Conclusion

Using Italy as a case study, we examined citizens’ preferences for an improved WMS. Overall, we found that individuals positively valuate improvements in the WMS, including an increase in waste-sorting categories, a more frequent and systematic waste collection, and the introduction of textile recycling. This shows citizens' enthusiasm to cooperate for a more efficient and sustainable WMS. We have also analysed how local contexts, environmental awareness values, and demographics shape individuals' preferences. We found that environmental awareness increases WTP for an improved WMS. Thus, environmental education campaigns may be an effective policy to increase WMS cooperation. In addition, we have uncovered how local contexts influence WMS preferences, highlighting the importance of context-specific WMS designs. Finally, we have found that socioeconomic variables have a significant impact on WMS preferences; they exert both an indirect impact, which emerges through the impact of demographics on environmental values, and a direct impact, which reflects other specific traits influencing decisions. Our results show that the direct impacts are generally higher than the indirect ones, pointing out that socioeconomics impact WMS preferences through specific traits that are not captured by environmental values. Future research could analyse the means by which demographics influence WTP for WMS.

CRediT author statement

Tatiana Cantillo: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualisation. **Sandra Notaro**: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualisation, Supervision. **Nicolao Bonini**: Writing - review & editing, Funding acquisition. **Constantinos Hadjichristidis**: Writing - review & editing, Funding acquisition

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