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Analysis

Consumers in a Circular Economy: Economic Analysis of Household Waste Sorting Behaviour

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ABSTRACT

The present research provides a quantitative assessment of households' preferences for different waste separation and handling schemes. We employ a choice-experiment based, nation-wide survey across Denmark. The findings support four different types of "waste sorters"; reflecting the heterogeneity in household waste sorting preferences. To illustrate, while one segment responds favourably towards sorting systems with the possibility for local collection points for hazardous waste and for sorting bio-waste, some segments express opposite responses. We found statistically significant relationships between the heterogeneity in household preferences for home waste sorting and households' sociodemographic characteristics, current self-reported time allocation for waste sorting and handling, use of recycling facilities as well as attitudinal factors on personal motivation and social influence. Furthermore, the findings reveal trade-offs between households' waste sorting preferences and the amount of time they have to spend sorting. We estimate a value of time for this pro-environmental activity of between 2.8 and 6.3 EUR per hour. Overall, the present research demonstrates that households express different preferences towards the practical design of waste sorting systems. This needs to be considered in the development of policy initiatives in order to achieve more effective sorting systems through higher rates of compliance from the public at large.

1. Introduction

The concept of a circular economy has garnered international attention over the last decade. For instance, developing a circular economy has become a focal point for the United Nations and is seen as vital for progress towards achieving several of the UN Sustainable Development Goals (UNIDO, 2017).

The European Union is among the global frontrunners in policy development in the field – e.g. by introducing the concept of the waste hierarchy in the 2008 EU Waste Framework Directive (Directive 2008/98/EC, 2008) and most recently by approval of new ambitious measures for developing a circular economy by the EU Member States in May 2018. According to the EU, 'the new legislation represents the most modern waste legislation in the world' (European Commission, 2018). Among the aims are ambitious targets for recycling of municipal waste (55% in 2025, 65% in 2035) and new recycling targets for packaging waste fractions[1] ranging from 30% (wood) to 85% (paper).

A prerequisite for increasing the circularity of resource flows in the economy is that waste is maintained in separate resource types. It is therefore important to analyse the implementation, effectiveness and cost of different waste handling and separation mechanisms. Despite the growing interest in the subject, most of the research efforts to date have taken a technical system perspective using tools such as life cycle analysis of waste resources in circular economy (e.g. Mik et al., 2016; Scheepens et al., 2016; Huysman et al., 2017). In general, studies into consumers' propensity to take part in the realization of circular economy are still lacking (Borrello et al., 2017).

In the present research, we investigate the factors shaping the propensity to engage in household sorting. We hypothesise that they will influence the likelihood of voluntary compliance with the rules of particular sorting and hence the effectiveness of the system. Based on previous studies we identify five factors that appear to be important for

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[1] Waste fractions refer to the different categories of waste according to their respective properties. The classification is particularly relevant in the context of sorting as different waste fractions require different ways of handling or treatment. Examples of waste fractions include paper, cardboard, plastics, electronics, batteries, organic or bio-waste, etc.

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the extent to which individuals object/agree to comply with behaviours expected in particular sorting schemes. The identified factors are 1) the extent to which the respondent believes that the scheme is meaningful, i.e. reduce important negative environmental impacts; 2) the extent to which the respondent believes that the recycling is effective, i.e. that the recycled material will re-enter into new product cycles; 3) the effort required to sort; 4) any additional nuisance of using the various sorting schemes; 5) the importance of existing facilities and other factors including habits, self-image and social influence for the motivations to sort. To better understand the relative strengths of these factors we specify a model to characterize the attractiveness of different sorting schemes to the household. We adopt a discrete choice experiment (DCE) method to investigate the trade-offs households make between various characteristics of different waste sorting schemes. DCE is a well suited method for eliciting preferences for outcomes which can be described by a set of attributes. The method has been widely used in different fields, however, to the best of our knowledge, its applications for quantifying household preferences for waste sorting schemes are still limited (except a few examples: Karousakis and Birol, 2008; Czajkowski et al., 2014, 2017; Lee et al., 2017).

This paper makes a contribution to the field in a number of ways. Firstly, in previous environmental economic studies investigating household preferences for waste separation, the waste sorting system has been largely described by the number of fractions to sort, for example 1 fraction (no sorting required), 2 fractions, 4 fractions, and so on (e.g. Czajkowski et al., 2014). In the present paper, we investigate how households' preferences for waste sorting schemes may differ according to the specific waste categories. Household waste consists of many different waste types and the environmental externalities and scope for resource re-utilisation varies significantly across categories. Focusing only on the number of sorting fractions is insufficient for environmental economic evaluation of alternative sorting systems. In this paper, we include attributes to explicitly indicate the types of waste to sort: Hazardous waste (e.g. chemicals, batteries, paint, nail vanish), plastics, and bio-waste to reflect the diversity of the waste. Sorting bio-waste is a relevant case as bio-waste makes up the large share of the total household waste quantity (e.g. Riber et al., 2009). Moreover, the sorting of bio-waste might exert inconvenience to households due to hygiene and unpleasant odours especially during hot summer seasons (e.g. Gilli et al., 2018). The degree of inconvenience can be an important factor reducing households' waste sorting and has been estimated in monetary terms – the so-called inconvenience cost – using DCE (Lee et al., 2017). Batteries, other hazardous waste and plastics present important environmental risk as these are among waste fractions with high content of hazardous chemical substances including mercury (Hg), lead (Pb), and cadmium (Cd) (Riber et al., 2009). Furthermore, while recycling of plastics is currently increasing, the environmental and economic rationales are being debated (Craighill and Powell, 1996; Gradus et al., 2017).

Secondly, in the existing economic literature, time has been suggested as a relevant variable in explaining households' waste sorting behaviour (e.g. Kipperberg, 2007; Huhtala, 2010; Gilli et al., 2018). However, the explicit treatment of time in the designs of previous studies has been limited (if not non-existent). The design of the research for the present paper makes it possible to make an explicit assessment of the cost of time incurred by households, which can potentially be included in cost-benefit analyses of alternative household waste sorting systems. Thirdly, while previous studies are largely more local in the coverage (e.g. specific neighbourhood, a city), the analysis for the present paper draws from a Danish nation-wide survey with a large sample size ($n = 1011$). As such, the present study encompasses the variation in preferences among households representing the national socio-demographic spread and existing variation in household waste recycling schemes. From the identification of household preferences, we develop a typology of waste sorters which reflect the heterogeneity of household preferences towards home sorting alternatives. This has potential relevance for the development of more flexible policy interventions for supporting more effective home waste separation schemes.

The overarching goal of the present research is therefore to quantify the scope for further decentralized waste sorting by assessing to what extent households are likely to opt for particular waste separation schemes and by investigating to what extent the designs of waste separation options shape households' willingness to engage in sorting activities.

The paper is structured as follows. Section 2 provides an overview of previous studies on household preferences for participating in different waste management programs. Section 3 describes the modelling approach and data collection process. Section 4 presents the findings of the research and section 5 discusses these in light of existing body of literature. Section 6 provides concluding remarks and policy insights.

2. Overview of existing economic literature on household waste sorting behaviour

Studies on household preferences for waste handling schemes to date have been approached using different scenarios. For example, using contingent valuation survey in Finland, Huhtala (2010) investigated household preferences over two different waste management systems: recycling versus incineration. According to her calculation, an 'average resident' would have much higher probability (72%) for choosing recycling over incineration (28%). Huhtala's findings point to income as an important determinant of the household preferences where high income households tend to express higher willingness to pay for incineration than recycling. Huhtala's interpretation of the finding is that recycling demands more effort and time and that opportunity cost of time is higher for households with higher income than those with lower income. Furthermore, under the assumption that a household spends between 15 and 45 min per week recycling, and that the use of spare time has a value of half the wage rate, Huhtala estimates the 'time cost' associated with recycling to be within the range of FIM 27–82 (4.54–13.8 EUR) per hour, in 1999.

Another example, a study by Lee et al. (2017), used a choice experiment to investigate people's preferences for and the inconvenience cost of waste sorting alternatives in South Korea. More specifically Lee et al. investigated to what extent waste sorting preferences are influenced by, among other things, the availability of an automatic sorting system in a central facility (with focus on food waste and recyclables), the option of a private company visiting and collecting waste from each individual household, and the hygiene level of the spot where households otherwise have to drop off their waste. Lee et al. found heterogeneity in the waste sorting preferences and the associated inconvenience costs. To illustrate this, even though an automated (centralized) sorting system would require less effort, some people still prefer to do the sorting themselves (manual). Moreover, the study shows that younger people express higher inconvenience cost compared with the older people.

Kipperberg and Larson (2012) employed a contingent rating experiment, and evaluated household preferences over five community recycling programs reflecting anticipated policy changes in the community recycling system in Seattle. Variation in the five programs was characterized by differences in the expected overall recycling rate and the estimated cost that each household has to bear per month. They reported variations in individual preferences and over the recycling programs. Their analysis also showed socioeconomic and attitude factors as determinants of the heterogeneity in respondents' preferences across different community recycling programs. For example, their findings showed that introducing a food waste recycling program was not particularly appealing to older respondents and male respondents while a positive preference was observed for respondents with higher educational level. While the findings of Huhtala (2010) clearly showed income as an important explanatory factor for household waste recycling preferences, the findings of Kipperberg and Larson (2012)

suggest that the relation between income and household preferences for recycling activities is not that straightforward. Kipperberg and Larson's study found household income only marginally significant for one specific program namely the prohibition of mixing recyclable items into general waste. A study from the UK showed statistically insignificant relationship between recycling rate and income (Abbott et al., 2011).

Some other studies investigated to what extent households prefer to sort waste at home as opposed to the alternative of leaving the waste sorting to be professionally handled by another party for example at a central facility. Differences in the findings from these studies are worth noting. For example, in a study by Bartelings and Sterner , 1999, 57% of the respondents would consider the possibility of not having to do the sorting themselves, however, only 40% of this group (i.e. 23% of the total respondents) expressed positive willingness to pay for such a service. The study reported an average WTP of 420 SEK (47.7 EUR), a figure which is about five times lower than the estimated value of sorting effort of 2500 SEK (283.9 EUR) which is based on the average number of hours spent on sorting and the average income per hour after tax. Another example, in a study from Norway by Bruvoll et al. (2000), 72% of the respondents would rather have the sorting conducted by a recycling company, albeit under the premise that the provision of such a service does not lead to additional expenses on the respondents. On the contrary, choice experiment based studies by Czajkowski et al. (2014, and again in 2017) reported that on average their respondents prefer to sort waste at home even if doing so incurs cost (including efforts and time) to the respondents. To illustrate, 70% of their respondents display a positive preference for sorting their household waste into five categories compared to not doing any sorting.

Previous research has shown that household choices to take part in more demanding waste handling schemes, such as recycling, can be explained by a multitude of factors. Household participation is influenced by the so called “inconvenience factor” because households have to make effort, to allocate space, and to give up time to undertake recycling activities (Huhtala, 2010; Sidique et al., 2010a; Czajkowski et al., 2017). These activities also incur extra household expenses e.g. due to the use of warm water for cleaning some of the materials (e.g. Bruvoll et al., 2000). The provision of waste collection set up and recycling infrastructure, which contributes to lessening the inconvenience factor, has also been shown as an important determinant (Gilli et al., 2018). To illustrate, travel distance to a drop-off recycling site has negative effects on the rate of visits to the site (Sidique et al., 2010a). Studies show that households display greater recycling activities under the curb side collection system than if the households themselves have to transport the recyclable materials to a collection station (e.g. Hong et al., 1993; Caplan et al., 2002; Karousakis and Birol, 2008; Sidique et al., 2010b; Gilli et al., 2018). Existing studies also show that more frequent collection systems tend to be preferred by households (e.g. Karousakis and Birol, 2008; Czajkowski et al., 2017). Furthermore, people express different preferences towards recycling programs depending on the expected recycling rate and how much it would cost the households to participate in the programs (Kipperberg and Larson, 2012). Some studies indicate that higher fees for waste disposals and the implementation of variable pricing of waste disposal would give people incentive to recycle more (e.g. Hong et al., 1993; Sidique et al., 2010b). However, a recent study from Norway (Heller and Vatn, 2017) suggests that the introduction of economic incentives, through a weight based fee on waste, trigger different responses. For some households, the scheme encourages them to sort more due to cost saving. In other words, these households respond positively to the external push brought about by the economic incentive. Meanwhile, the introduction of economic incentive does not change the degree of sorting done by those households who are self-motivated; that they do not end up sorting more after the introduction of the scheme. Heller and Vatn (2017) argue that this illustrates that people motivated by environmental concerns may question the justification of an economic incentive scheme, and as a result the scheme can be counterproductive. A recent study from Italy by Gilli et al. (2018) shows that the efficacy of policies to promote recycling is very much dependent on individual motivations.

Another line of research has uncovered the important role of personal belief, moral aspects, social norms and social interactions. A recent study by Czajkowski et al. (2017), based on a survey in a neighbourhood in Poland, revealed that the majority of the household respondents prefer to sort themselves primarily because they believe it would not be done as thoroughly at a central facility. This highlights the importance of trust in the system, and it has been evidenced that reports about sorted waste ending up in incineration facilities have reduced the motivation to sort (e.g. Ingeniøren, 2012; Bolius, 2016). Some studies have shown that the propensity to participate in recycling schemes is closely related to the degree to which individuals perceive recycling as their moral obligation, that they are doing the right thing for the environment, and that they hold a sense of personal responsibility for sorting (e.g. Bruvoll et al., 2000; Berglund, 2006; Nyborg et al., 2006; Brekke et al., 2010; Heller and Vatn, 2017). For some individuals, doing so is part of maintaining their self-image (Nyborg et al., 2006; Brekke et al., 2010; Czajkowski et al., 2017). Previous research reveals that individuals' recycling behaviour is also influenced by views and behaviours with regard to recycling of those within the individuals' community or social network. Individuals are more likely to recycle when their family and friends also share the idea that recycling is an activity worth pursuing. In the same vein, individuals are more likely to put greater efforts into recycling when they think that their neighbours and others in their community are also doing their share. The role of social influence is particularly important to individuals when they are not certain about their personal recycling responsibility (Brekke et al., 2010). Finally, previous studies have reported a number of socio-economic determinants of household waste handling behaviours including age, income, household size, and employment (e.g. Hong et al., 1993; Huhtala, 2010; Sidique et al., 2010a, 2010b; Kipperberg and Larson, 2012; Lee et al., 2017).

3. Methods and data

3.1. Model specification

We use a choice modelling approach to quantify the importance of different factors in household's preferences for different waste sorting schemes. This follows the same approach as other economic studies analysing household's waste sorting and recycling preferences (Kipperberg, 2007; Huhtala, 2010; Czajkowski et al., 2014; Lee et al., 2017). The approach follows the standard random utility framework, where the utility that respondent n gains from waste sorting alternative j is specified as (Adamowicz et al., 1998):

$$U_{nj} = V_{nj} + \varepsilon_{nj}. \quad (1)$$

As such, the first component, V_{nj}, is the deterministic component of individual n's utility, captured through the attributes of the waste sorting and handling alternative j. Based on the literature, we define V_{nj} as a linear function of seven waste sorting attributes. The first three attributes concern the type of waste to be separated, as the respondents may attach different level of importance to recycling waste with different environmental impact profiles. Furthermore, different types of waste may also involve different levels of nuisance to the households. The three types of waste are hazardous waste, plastics and bio-waste. The fourth attribute reflects the effectiveness of the system in terms of reuse of the material, i.e. percentage of the material that will re-enter the economic system as new products. The fifth attribute measures the effort (time) required by the household to sort, and the sixth and seventh attributes capture the level of service and cost respectively. These factors are measured as the frequency of waste collection and the annual fee for waste collection and handling (Table 1).

The second component, ε_{nj}, is a random component of the utility

Table 1
List of attributes for home waste sorting choices.

Attributes	Definition	Levels
Hazardous waste	How households should handle hazardous waste	1. Households can dispose of this waste category in a special container that is installed locally < 100 m from their residence 2. Households must drive and drop off this waste category at a designated facility
Plastics	How households should handle plastic waste	1. Households are required to sort plastic waste 2. Households are NOT required to sort plastic waste
Bio-waste	How households should handle bio-waste	1. Households are required to sort bio-waste 2. Households are NOT required to sort bio-waste
Recycling capacity	The proportion of the sorted waste that eventually gets recycled. This reflects the capacity of the company/municipality that recycles sorted waste.	1. 50% 2. 60% 3. 70% 4. 75% 5. 85% 6. 95%
Time use	The amount of time households are expected to spend weekly on sorting and handling waste. This includes time used for cleaning waste before putting the waste into the specified containers, time used for driving to designated waste collection facility etc.	1. 10 min per week 2. 15 min per week 3. 25 min per week 4. 30 min per week 5. 50 min per week 6. 60 min per week
Frequency of waste collection	The frequency of waste collection by the municipality	1. Twice a week 2. Once a week 3. Fortnightly
Waste collection and handling fee	Annual bill that households must pay to the municipality for waste collection and handling service	1. 1500 DKK per year 2. 2500 DKK per year 3. 3000 DKK per year 4. 3700 DKK per year 5. 4000 DKK per year 6. 4500 DKK per year

function. Assuming that this term is distributed independently and identically (iid) across respondents and alternatives, it specifies the standard Conditional Logit Model (CLM) and the probability of respondent n choosing alternative j is:

$$P_{nj|J} = \frac{e^{\beta X_j}}{\sum_{k \in J} e^{\beta X_k}} \quad (2)$$

In this framework, we include the importance of current sorting and recycling habits, internal motivation (self-image) and social influence or interaction as factors potentially explaining the heterogeneity in preferences across households. These factors are captured by asking respondents to indicate the extent to which they agree or disagree to each of six statements: three statements related to internal motivation and the other three for capturing social influence (see the last six variables in Table 2). To quantify potential heterogeneity in respondents' preferences for waste sorting and handling alternatives, we estimate a Latent Class Model (LCM) (Boxall and Adamowicz, 2002; Greene and Hensher, 2003; Train, 2003). Following the LCM framework, the latent heterogeneity of household waste sorting preferences is captured by assigning households into S number of segments. LCM therefore identifies individual segments ($s = 1,\ldots,S$) and the utility function for respondents in each segment can now be expressed as:

$$U_{nj|s} = \beta_s X_{nj} + \varepsilon_{nj|s}. \quad (3)$$

Following this, the probability of choosing waste sorting j among J alternatives for respondent n belonging to segment s ($P_{ns|(j)}$) can be calculated (Greene and Hensher, 2003):

$$P_{ns|(j)} = \frac{e^{\beta_s X_j}}{\sum_{k \in J} e^{\beta_s X_k}} \quad (4)$$

Each respondent n has a probability to belong to any segment even though the association of respondents to segments is not known. The probability of segment membership, P_{ns}, is specified as constant probabilities that sum to one across the segments, S. The resulting likelihood of respondent n choosing a waste sorting and handling alternative j ($P_{n(j)}$) is equal to the sum over all latent classes s of the class-specific membership model conditional on the product of class $P_{n|s(j)}$ and the probability of belonging to that class P_{ns} (Swait, 1994):

$$P_{n(j)} = \sum_{s=1}^{S} P_{ns}\, P_{ns|(j)} \quad (5)$$

We explore the association between class or segment membership and the respondents' socio-economic characteristics, current waste sorting and recycling habits and attitudes towards sorting in their community. We use a Latent Class framework following the argument previously made by others (see Boxall and Adamowicz, 2002; Beharry-Borg et al., 2013), that the LCM offers relevant and practical insights for policy developments on the heterogeneity of the target population. Continuous specification of the distribution of preferences, using a mixed logit specification, often reveals less insight for policy making. We use Nlogit version 5 to estimate the models (Greene, 1986–2012).

3.2. Calculation of willingness to pay for different levels of recycling and inconvenience cost

We calculate the household average willingness to pay for changes in scheme requirements for sorting of waste and other scheme attributes. As the coefficient, β_k, for the sorting attribute k measures the change in the attractiveness of a scheme if sorting is required, the coefficient for waste collection fee, β_f, measures the importance that the households place on the fee. The relative value of the coefficients, (β_k/β_f), therefore reflects the trade-off households are willing to make between sorting of additional waste fractions and the collection fee. Assuming that collection fee has a negative impact on households, a positive coefficient on the sorting fraction would indicate that households would be willing to pay a higher collection fee for waste schemes where additional sorting would be required. In the same way a negative coefficient on a sorting fraction would indicate that households would not be willing to accept higher collection fees for schemes with requirements to sort. In this way, the relative values of the coefficients measures the relative importance of the different attributes of the waste

Table 2
List of variables included in the probit analysis.

Variables	Descriptions of variables
Age	Age of the respondent (years); Continuous
Gender	Dummy: Female = 1, Male = 0
Long higher education	Dummy: =1 if the respondent has completed higher education for 5 years or longer, =0 otherwise
Middle higher education	Dummy: =1 if the respondent has completed 3–4 years of higher education, =0 otherwise
Short higher education	Dummy: =1 if the respondent has completed up to 3 years of higher education, =0 otherwise
High school education	Dummy: =1 if high school ("gymnasium") is the respondent's highest education level, =0 otherwise
Entrepreneurship education	Dummy: =1 if entrepreneurship education is the respondent's highest education level, =0 otherwise
Retired	Dummy: =1 if the respondent is retired, =0 otherwise
Student	Dummy: =1 if the respondent is a student, =0 otherwise
Skilled worker	Dummy: =1 if the respondent is a skilled worker, =0 otherwise
White collar (non-managerial)	Dummy: =1 if the respondent is a white collar with non-managerial responsibility, =0 otherwise
White collar (manager)	Dummy: =1 if the respondent is a white collar with managerial responsibility, =0 otherwise
Household size	Total number of people living in the household; Continuous
Apartment	Dummy: =1 if the respondent living in an apartment, =0 otherwise
Villa/Single-family house	Dummy: =1 if the respondent living in a villa or single-family house, =0 otherwise
Other types of housing	This refers to all respondents living in accommodation types other than apartment and villa or single-family house. This is essentially the base category for the accommodation type dummies.
Current sorting effort	Amount of time the household respondent typically spends on waste sorting and handling (minutes per week); Continuous
Use of recycling centre > 5 times a year	Dummy: =1 if the respondent use the recycling centre > 5 times a year, =0 otherwise
Region level 1	Dummy: East = 1, West = 0
Region Hovedstaden	Dummy: =1 if the respondent residing within Region Hovedstaden, =0 otherwise
Region Midtjylland	Dummy: =1 if the respondent residing within Region Midtjylland, =0 otherwise
Region Sjælland	Dummy: =1 if the respondent residing within Region Sjælland, =0 otherwise
Region Syddanmark	Dummy: =1 if the respondent residing within Region Syddanmark, =0 otherwise
Region Nordjylland	This refers to all respondents residing within Region Nordjylland. Essentially this is the base category for the region dummies.
Sorting consciousness	Dummy: =1 if the respondent agrees to the statement "I get bad consciousness when/if I do not sort my waste", =0 otherwise
Time for the environment	Dummy: =1 if the the respondent agrees to the statement "I do not mind spending so much time on waste sorting in my household because I am doing something good for the environment", =0 otherwise
Lifestyle for the environment	Dummy: =1 if the respondent agrees to the statement "I care very much about the environment and the impacts of my lifestyle on the environment", =0 otherwise
Scepticism on others	Dummy: =1 if the respondent agrees to the statement "Even if I do sort, I am not sure if others would actually sort their household wastes properly", =0 otherwise
Collective work	Dummy: =1 if the respondent agrees to the statement "I think it is important to work collectively with my neighbours on waste sorting", =0 otherwise
My neighbours' judgement	Dummy: =1 if the respondent agrees to the statement "My neighbours will judge me negatively if I do not sort my household waste", =0 otherwise

sorting alternatives for the different segments as identified through the Latent Class Model (LCM).

Using the same logic, we also derive the implied average value of time, an inconvenience cost, that households place on home waste separation. This implied value of time is equal to the ratio of the coefficient for time attribute and the price (waste collection and handling fee attribute) coefficient from the choice model.

3.3. Characterizing waste sorting segments

We use probit analysis to examine to what extent sociodemographic characteristics, respondents' current habits on sorting and recycling, internal (personal) motivation as well as external (social) influence relate to the heterogeneity of household preferences for waste sorting alternatives (the last six variables in Table 2). In the analysis, respondents' membership to one of the segments as identified through the Latent Class Model serves as the dependent variables and household sociodemographic characteristics, recycling habits and personal and external influences as predictors. The respondents are assigned to the segment for which the membership probability is highest. For each segment, first all predictors (presented in Table 2) were included in the model specification and then the best model was selected following stepwise method in STATA (StataCorp, 2009). Significance level for removal of the variables from the model was set to 0.1.

3.4. Data collection

We collected data through an online survey targeting households across Denmark. The first task in developing the DCE design was to identify a wide range of factors that would be relevant for inclusion as attributes of different waste sorting schemes. The subsequent task was to define appropriate levels for each chosen attribute. The initial list of relevant factors was collated based on a literature review. In the end, seven attributes were selected and included in the DCE (Table 1).

In the questionnaire, we tried to avoid bias by careful consideration of the neutrality, ambiguity and complexity of the questions (Choi and Pak, 2005). We aimed at having a reasonable amount of response categories in each section of the questionnaire to avoid 'drop outs' and tried to avoid yea- and nay-saying by having questions turned in different directions. Questions were carefully phrased to aim at having them at a neutral level to avoid pleasing effects etc. (see Choi and Pak, 2005). Ultimo November 2017 we invited 7 persons to test a draft questionnaire, received comments, revised the questionnaire, and reduced the length of the survey to avoid respondent fatigue (see Choi and Pak, 2005). We then conducted a pilot survey with 60 respondents and provided space at the end of the questionnaire for the respondents to provide comments. No concerns were raised to the questionnaire, and we were therefore assured that the content of the questionnaire including the choice experiment set-ups appeared realistic to the respondents.

In the choice experiment, each respondent was presented with eight choice tasks. For each task a respondent was asked to choose one of three waste sorting and handling options or a none option which refers to the option of not choosing any of the presented sorting scenarios. This none option alternative does not have attribute levels associated with it and is specified only as the alternative specific constant. Several studies have adopted a similar approach (e.g. Christensen et al., 2011; Greiner, 2016; Rose and Hess, 2009).

There were three questionnaire versions (blocks), each with 8 choice tasks and the respondents were randomly assigned to one of the

	Scenario 1	Scenario 2	Scenario 3	None
Hazardous waste	Local collection point	Drop off to central facility	Drop off to central facility	
Plastic	Required to sort	Not required to sort	Not required to sort	
Bio-waste	Not required to sort	Not required to sort	Required to sort	
Time use	10 minutes	50 minutes	50 minutes	
Recycling	95%	60%	70%	
Frequency of waste collection	Twice a week	Once every two weeks	Twice a week	
Cost	1,500 DKK	4,500 DKK	4,000 DKK	
Which option would you choose?	○	○	○	○

Fig. 1. Example of a choice card.

three versions. Furthermore, following Carlsson et al. (2012), the choice sets were presented to the respondents in randomised sequences in order to mitigate any ordering effect. The design of the experiment was optimised based on the D-Efficiency score of the multinomial logit (MNL) model with assigned priors. The D- and A-Error of the final design are 0.0263 and 1.1293 respectively. The parameter estimates based on the results of the pilot (60 respondents) were then used to re-adjust the priors hence to revise the design of the choice experiment. An example of a choice card can be seen in Fig. 1.

The survey was administered online by the consultancy company Userneeds. The survey was finally launched in the period December 28th, 2017 to January 3rd, 2018. An invitation to participate in the survey was sent to 7801 households in Denmark who were members of the Userneeds panel (Userneeds, e-mail communication, 04.01.18). The survey was terminated when the initially agreed number of complete responses was reached i.e. 1011 respondents completed the questionnaire.

Given the set-up of the survey administration, information on response rate is not available. Instead, we use drop-out-rate, which indicates the proportion of the respondents who started yet did not complete the questionnaire. The drop-out rate of the present survey is 16 pct., which Userneeds characterizes as a 'very good' result. In general, if the drop-out-rate is higher than 30 pct., Userneeds normally analyses whether there were problems/mistakes in the questionnaire (Userneeds, e-mail communication, 04.01.18).

Collected socio-economic data and other variables considered relevant for modelling waste sorting behaviour are specified in Table 2. The last six variables listed in Table 2 capture internal (self-image) motivation and social influence on respondents' choices for household waste sorting.

4. Results

4.1. Demography of the household respondents

Table 3 reports on a range of the survey respondents' socio-demographic characteristics and the comparison between the distribution in the sample and the national figures. The respondents in the sample had an average age of 48 years with 50 pct. male and 50 pct. female. Most of the respondents were located in Region Hovedstaden (30 pct.) and fewest in Region Nordjylland (10 pct.). Most of the respondents live in single-family houses and apartments. The most frequent level of education of the respondents is medium long education. The occupation of the respondents varies with most being non-manual workers with no management responsibility (25 pct.) or retired (23 pct.). The median income of the respondents' household income before tax is in the interval 500.000–599.999 DKK (not shown in table). The most frequent size of the households (including the respondent) is two persons (56 pct.).

Table 3
Key socioeconomic characteristics of the respondents.

Variables	Categories	Sample distribution (% of total respondents)	National distribution (%)
Age (years)	18–34	27.2	29.9
	35–53	35.4	34.7
	54–75	37.4	35.4
Gender	Female	50.0	49.9
	Male	50.0	50.1
Education	Vocational education	18.8	30.3
	Primary school	6.5	26.4
	Upper secondary school	10.0	9.9
	Short higher education	13.6	4.8
	Medium long education	31.7	16.6
	Long higher education	18.6	9.8
	Others	0.7	2.2
Household size	1	29.0	38.0
	2	56.0	33.7
	3	11.0	11.9
	4	3.0	11.1
	5 or more	1.0	5.4
Type of housing/ accommodation	Villa/single-family house	48.5	43.7
	Apartment	33.4	38.8
	Others	18.1	17.5
Household annual income before tax (DKK)	< 300,000	29.35	37.76
	300,000–599,999	36.13	32.65
	600,000 and higher	34.52	29.6
Region	Region Hovedstaden	30.0	31.5
	Region Midtjylland	22.7	22.7
	Region Nordjylland	9.6	10.2
	Region Sjælland	15.4	14.4
	Region Syddanmark	22.3	21.1

Our sample is fairly consistent with the national distribution for key variables such as age, gender, and geographical distribution. Nonetheless, there is also a notable discrepancy in terms of the representation of households in the low-income category and those with more members in the households. In addition, we have slightly more representation of households within the high-income categories[2] in our

Table 4
Results from CLM and LCM on household waste sorting scenarios.

Attributes of household waste sorting and handling options	Parameter estimates				
	CLM	LCM Segment 1	LCM Segment 2	LCM Segment 3	LCM Segment 4
Hazardous waste	−0.0215	−0.3163***	−0.2124	2.3677***	−0.3676***
	(0.0413)	(0.1216)	(0.1649)	(0.2167)	(0.0890)
Plastics	0.4412***	0.5281***	0.5715***	1.2794***	0.2997***
	(0.0492)	(0.1507)	(0.1935)	(0.2082)	(0.1129)
Bio-waste	−0.0962**	0.1492	−0.3200	0.3415**	−0.3389***
	(0.0393)	(0.1135)	(0.1644)	(0.1584)	(0.0834)
Time	−0.0136***	−0.0248***	−0.0192***	−0.0133***	−0.0105***
	(0.0011)	(0.0035)	(0.0039)	(0.0038)	(0.0026)
Recycling capacity	0.0072***	0.0247***	0.0254***	0.0085	0.0113***
	(0.0018)	(0.0061)	(0.0086)	(0.0070)	(0.0039)
Waste handling fee	−0.0008***	−0.0014***	−0.0006***	−0.0005***	−0.0003***
	(.3201D-04)	(.9803D-04)	(0.0001)	(0.0001)	(.7364D-04)
Frequency (3 levels):					
1 = once every two weeks	0.3666***	0.7470***	0.1028	−0.0892	−0.0306
	(0.0471)	(0.1332)	(0.1751)	(0.1832)	(0.1044)
2 = once a week (base level)					
3 = Twice a week	−0.1070***	0.0965***	−0.2892	0.0558	0.1091
	(0.0414)	(0.1187)	(0.1657)	(0.1541)	(0.0924)
Alternative specific constant	−1.9818***	−4.3399***	2.0538	1.2968	−2.9353***
	(0.2645)	(0.8092)	(1.1587)	(1.0412)	(0.5899)
Class share		46%	17%	15%	22%
Log likelihood	−8499.88	−6862.77			
AIC	17017.8	13803.5			

Standard errors are reported in (parentheses).
*** Indicates significance at 1% level.
** Indicates significance at 5% level.

sample compared with the national distribution (Statistics Denmark, 2019). In the same vein, our sample has more households with higher education levels than those with primary and vocational educational levels.

4.2. Results from choice modelling

Table 4 presents the results from the Conditional Logit Model (CLM) and the Latent Class Model (LCM). The models are estimated based on complete responses from 1011 respondents. Only 5.6% of the total respondents choose the 'None' option in all choice cards presented to them. This suggests that the waste sorting options presented in the survey are considered realistic by the respondents. We also estimated a model that included the interaction terms between the time attribute and the individual waste categories. These interaction terms are not statistically significant which supports the initial model specification, as the attribute time reflects the intensity of effort for the overall sorting for a given scheme hence not attached to a specific waste category.

In this section, the focus is on the statistical significance and direction of impact of the individual attributes. We return to the magnitude of the individual parameter estimates in the following section and estimate willingness to pay (WTP) for the different choice attributes (reported in Table 5; section 4.3). The results from the CLM show that 6 out of 7 attributes included in the present choice experiment study are statistically significant ($p < 0.05$) in explaining household choices on waste sorting and handling alternatives (Table 4).

We estimate four Latent Class Choice Models with 2, 3, 4, and 5 individual segments respectively. Based on the key model statistics (log likelihood and AIC) we conclude that a LCM with 4 segments gives a good fit to the data and we choose this LCM model for our further analysis.

As can be seen from the parameter estimates for the LCM (Table 4), there are some similarities between the four segments in terms of what influences their preferences for waste sorting schemes. All segments demonstrate a positive preference towards schemes which involve sorting of plastic. Conversely, as expected, the attributes time and waste handling fee are statistically significant and negative across all segments. This shows that households are most likely to get discouraged by waste handling schemes that are expensive and burdensome in terms of time allocation for home waste sorting. Furthermore, the parameter attribute for recycling capacity is statistically significant and positive for all segments but one. This indicates that households belonging to the three segments (1, 2, and 4) are more likely to take part in waste sorting programs if they trust that a large proportion of the sorted waste will actually get recycled. For segment 3, the preference for household waste sorting does not seem to be sensitive to recycling capacity as indicated by the non-statistically significant parameter estimate for recycling capacity attribute for this segment.

The results of the LCM also highlight some differences between the identified segments (see Table 4). Respondents in segment 1 prefer schemes with the requirement to drop off hazardous waste to a designated facility typically located further away from their residential areas. This can be seen from the statistically significant and negative parameter estimate for hazardous variable for segment 1. In addition, respondents in segment 1 are clearly in favour of waste sorting and handling systems with less frequent waste collection. However, respondents in segment 1 do not have a clear opinion on the requirement to sort bio-waste. Approximately 46% of the survey respondents belong to segment 1. We identify households in segment 1 as 'the frequent waste collection resisters' (S1).

Segment 2 covers around 17% of the survey respondents (Table 4). The preferences of respondents in segment 2 for waste sorting and handling alternatives are largely comparable to those belonging to segment 1. However, while the coefficient for local collection of hazardous waste for segment 1 is statistically significant and negative, the parameter for the same attribute is statistically non-significant for segment 2. This indicates that respondents in segment 2 appear to be less sensitive to arrangement for hazardous waste handling and collection compared to those in segment 1. Moreover, compared to

[2] Of the total 1011 respondents, 811 indicated their income level while 161 opted 'do not wish to answer' and 39 'don't know'.

segment 1, the importance of recycling capacity is more pronounced in determining the preferences for waste sorting schemes by households in segment 2. This indicates that segment 2 finds it important that the municipality actually has the capacity to utilise the sorted waste. We identify households in segment 2 as 'the sceptics' (S2).

Segment 3 covers approximately 15% of the survey respondents. In general, of all the segments identified through LCM, respondents in segment 3 demonstrate the most positive view on sorting of plastics and bio-waste, and at the same time they reveal a clear preference for the possibility to dispose hazardous waste to allocated container within the vicinity of their residences. The parameter estimates for the attributes hazardous waste, plastic and bio-waste are statistically significant and positive (see Table 4). Interestingly, in contrast to the other segments, the parameter estimate for recycling capacity is statistically non-significant for segment 3 which may suggest that the preferences for waste sorting and handling schemes by respondents in segment 3 seem to be less dictated by the intensity of recycling of the sorted waste. Finally, the respondents in segment 3 appear to be less concerned about how often the municipality collects the waste as indicated by the coefficient for the attribute frequency being statistically non-significant. We identify households in segment 3 as 'the sorting enthusiastic' (S3).

The key distinguishing features of segment 4, making up 22% of the survey respondents, are the statistically significant and negative parameter estimates for the attributes bio-waste and hazardous waste (Table 4). These findings suggest that respondents in segment 4 are not interested in waste sorting and handling schemes, which require them to separate bio-waste. In addition, respondents in segment 4 are not in favour of having local collection points for hazardous waste. Furthermore, the preferences for waste sorting schemes by respondents in segment 4 seem to be less influenced by the frequency of waste collection as indicated by the statistically non-significant parameter estimate for the corresponding attribute. We identify households in segment 4 as 'the bio-waste sorting resisters' (S4).

4.3. Implied value of time (inconvenience cost) and household willingness to pay for different levels of sorting

Based on the parameter estimates for time use and waste collection and handling fee attributes (see Table 4) we calculate the average value of time (see section 3.2 regarding the calculation method) for waste sorting activities for households in each of the four segments. This implied value of time, in the context of the present research, indicates how much these households are willing to pay in order to spend 1 h less per week on sorting. The implied value of time is highest for 'the bio-waste sorting resisters' (S4) at 46.69 DKK (6.28 EUR) per hour followed by 'the sceptics (S2)' and 'the sorting enthusiastic (S3)' at 35.15 DKK (4.72 EUR) and 31.32 DKK (4.21 EUR) respectively. The lowest implied value of time is observed for 'the frequent waste collection resisters (S1)' at 20.72 DKK (2.78 EUR).

Household willingness to pay (see section 3.2 regarding the calculation method) for selected attributes of the waste sorting alternatives presented to the respondents in the choice experiments provide a consistent basis for comparing household preferences (Table 5). In general 'the sorting enthusiastic (S3)' are keen on having the possibility to dispose of hazardous waste in an area within close proximity to their residence. For such a service, they seem to be willing to pay close to 5000 DKK (650 Euro), which indicates that the option to have a local collection of hazardous waste has a high importance for this particular household group. On the contrary, 'the frequent waste collection resisters (S1)' and 'the bio-waste sorting resisters' (S4) are not in favour of the installation of local disposal points for hazardous waste as indicated by their negative willingness to pay values. In this regard, 'the bio-waste sorting resisters' (S4) are 7 times more reluctant than 'the frequent waste collection resisters (S1)' are.

Household preferences for the option to sort plastic are positive across all segments with 'the sorting enthusiastic' (S3) and 'the bio-waste sorting resisters' (S4) having the largest willingness to pay for sorting plastics at 2611 DKK (351 Euro) and 1153 DKK (155 Euro) respectively. This suggests that 'the sorting enthusiastic' (S3) and 'the bio-waste sorting resisters' (S4) are more keen to sort plastics than 'the frequent waste collection resisters' (S1) and 'the sceptics' (S2) are. Our analysis further suggests that, keeping other factors constant, the amount of time households in the different segments are willing to spend on sorting plastics is varied: 21 min per week for 'the frequent waste collection resisters' (S1), approximately 30 min for 'the sceptics' (S2) and 'the bio-waste sorting resisters' (S4), and 96 min for 'the sorting enthusiastic' (S3). This indicates that although household preferences for sorting plastic are positive in general, the introduction of a system that requires more effort (hence to spend longer time) will reduce their utility gain from plastic separation. The results confirm that 'the sorting enthusiastic' (S3) are the most interested in sorting plastics; the amount of time they are willing to spend on waste separation is three to four times as much as what the other segments are willing to allocate.

Contrasting preferences among segments towards the requirement to sort bio-waste are evident. While 'the sorting enthusiastic' (S3) display a positive WTP for sorting bio-waste at around 700 DKK (94 Euro), a negative WTP is observed for 'the bio-waste sorting resisters' (S4) at twice the magnitude. This shows that for households belonging to the segment 4, sorting bio-waste accrues substantial inconvenience cost. In general, recycling capacity has a positive influence on household preferences for home waste separation. Nevertheless, the WTP estimates show that the likely effect of increase in recycling capacity on preferences for home waste sorting are more pronounced (slightly more than twice as much) on 'the sceptics' (S2) and 'the bio-waste sorting resisters' (S4) compared with 'the frequent waste collection resisters' (S1).

The frequency of waste collection appears to be of concern only for 'the frequent waste collection resisters' (S1). The findings show that 'the frequent waste collection resisters' (S1) are reluctant to choose frequent waste collection in general.

4.4. Drivers of the waste sorter typology

Findings from the probit analysis offer insights into the extent to which sociodemographic characteristics relate to the heterogeneity of household preferences for waste sorting alternatives (Table 6). The results also indicate the importance of habits and personal and social motivation for waste sorting. Parameter estimates in Table 6 are from the best specification for each segment following stepwise estimation. As such, Table 6 only reports the variables appearing in the best specification. Marginal effects are provided in Appendix 1. It is important to note that, as indicated by the pseudo R2 values reported in Table 6, in general the explanatory power of households' socio-demographic characteristics and attitudinal factors in explaining the heterogeneity of households' waste sorting preferences is low.

The results show that households that frequently use the recycling centre are more likely to belong to segment 1 – 'the frequent waste collection resisters (S1)'. Households in this segment are driven by self-consciousness to sort waste. For segment 2 – 'the sceptics (S2)', gender turns out to be an important predictor where male respondents are more likely to belong to this segment than female respondents are. This segment is also characterized by households who live in villas/single-family houses and who are not frequent users of the recycling centre. Moreover, households are unlikely to belong to this segment if they are self-conscious about sorting and about the impacts of their lifestyle choices on the environment. In the same vein, households who are concerned about their neighbours' judgement on their waste sorting behaviour are unlikely to belong to this segment.

Segment 3 – 'the sorting enthusiastic (S3)' is characterized by respondents being female, living in apartments, and non-students. In addition, households in segment 3 are not keen on travelling to and

Table 5
Household's willingness to pay for different features of waste sorting alternatives.

Willingness to pay (per year) for:	'The frequent waste collection resisters' (S1)	'The sceptics' (S2)	'The sorting enthusiastic' (S3)	'The bio-waste sorting resisters' (S4)
Local collection point for hazardous waste	−229.20 DKK (−30.81 Euro)	−337.13 DKK (−45.32 Euro) (ns)	4832.14 DKK (649.60 Euro)	−1413.77 DKK (190.06 Euro)
Option to sort plastic	382.71 DKK (51.45 Euro)	907.22 DKK (121.96 Euro)	2611.02 DKK (351.01 Euro)	1152.77 DKK (154.97 Euro)
Option to sort bio-waste	108.12 DKK (14.53 Euro) (ns)	−507.95 DKK (−68.28 Euro) (ns)	696.90 DKK (93.69 Euro)	−1303.38 DKK (−175.22 Euro)
Recycling capacity	17.90 DKK (2.41 Euro)	40.30 DKK (5.42 Euro)	17.37 DKK (2.33 Euro) (ns)	43.58 DKK (5.86 Euro)
Frequency of waste collection: once every two weeks (as opposed to once a week)	541.27 DKK (72.76 Euro)	163.24 DKK (21.94 Euro) (ns)	−182.08 DKK (−24.48 Euro) (ns)	−117.77 DKK (−15.83 Euro) (ns)
Frequency of waste collection: twice a week (as opposed to once a week)	69.89 DKK (9.39 Euro) (ns)	−459.09 DKK (−61.72 Euro) (ns)	113.98 DKK (15.32 Euro) (ns)	419.81 DKK (56.43 Euro) (ns)

ns: not statistically significant (p value > 0.05).

Table 6
Results from probit analysis: socio-demographic and attitudinal determinants of segmentation of household waste sorting preferences.

Variables	Parameter estimates			
	Segment 1 – 'the frequent waste collection resisters' (S1)	Segment 2 – 'the sceptics' (S2)	Segment 3 – 'the sorting enthusiastic' (S3)	Segment 4 – 'the bio-waste sorting resisters' (S4)
Gender (Female = 1)	na	−0.3140*** (0.1173)	0.3128*** (0.1132)	na
Student (Yes = 1)	na	na	−0.4900** (0.2183)	na
White collar (non-managerial) (Yes = 1)	na	na	na	−0.2805** (0.1183)
Apartment (Yes = 1)	na	na	0.3147** (0.1320)	na
Villa/single-family house (Yes = 1)	na	0.3154** (0.1309)	na	na
Region Midtjylland	0.1980 (0.1064) (ns)	na	na	na
Current sorting effort (minutes per week)	na	na	na	0.0076*** (0.0027)
Use of recycling centre > 5 times a year (Yes = 1)	0.2480*** (0.0901)	−0.2667** (0.1301)	−0.4118*** (0.1288)	na
Sorting consciousness	0.3766*** (0.0943)	−0.2797** (0.1260)	na	−0.3336*** (0.1017)
Lifestyle for the environment	na	−0.2534** (0.1260)	na	na
Collective work	0.1826 (0.0935) (ns)	na	−0.2455** (0.1202)	na
My neighbours' judgement	na	−0.5369*** (0.1984)	na	na
Constant	−0.5058*** (0.0938)	−0.5973*** (0.1198)	−1.0073*** (0.1238)	−0.6585*** (0.0959)
Pseudo R2	0.0320	0.0667	0.0569	0.0274

Standard errors are reported in (parentheses).
ns = not statistically significant (*p* value > 0.05).
na = removed during stepwise estimation (*p* value > 0.1) hence not appear in the specification of the selected model.
*** Indicates significance at 1% level.
** Indicates significance at 5% level.

using the recycling centre. Moreover, the results show that respondents who agree with the statement that it is important to work together with their neighbours on waste separation are less likely to belong to segment 3. In other words, the waste sorting behaviours of households in this segment do not appear to be driven by the role of collective efforts on waste sorting.

Respondents currently spending relatively a lot of time on waste sorting and handling tend to belong to segment 4 - 'the bio-waste sorting resisters (S4)'. The marginal effects (Appendix 1) indicate that a change in the current time allocation for waste sorting by 1 min per week leads to an increase in the probability by 0.0022 for a household to belong to segment 4. Employment status also appears to be an important determinant of segment 4. The results indicate that respondents with "White collar (non-managerial)" employment are less likely to be 'the bio-waste sorting resisters' (S4). Moreover, respondents having self-consciousness towards waste sorting are also less likely to belong to this segment.

5. Discussion

Drawing on a national scale choice-experiment survey (n = 1011), the present research offers new insights into household preferences for waste sorting and handling in Denmark. We investigated the micro-economic aspects of household waste sorting preferences in Denmark, with the focus to investigate household preferences for different modes of home waste sorting. More specifically, households were able to evaluate and hence make trade-offs between the following factors: alternative arrangement for disposal of hazardous waste, requirement for sorting plastic and bio-waste, time demand for waste sorting and handling, the capacity for recycling at municipality level, the frequency and the fee of waste collection and handling service by the municipality.

Previous choice-experiment studies have analysed respondents' evaluation of the complexity of home waste sorting through the inclusion of an attribute for the number of waste categories to be sorted. Based on a study on kerbside recycling services in London, Karousakis and Birol (2008) found that their respondents were more likely to choose kerbside services that collect more waste categories. In the same vein, Czajkowski et al. (2014) and Czajkowski et al. (2017) found that, based on a study in Poland, their respondents preferred to sort waste into more categories compared to fewer categories. While the previously mentioned studies show that the respondents are more likely to choose a home sorting system with more waste categories, the contrary was reported by Sakata (2007). Reporting on a study from Japan, Sakata (2007) found that increasing the number of categories to sort,

results in negative utility for the respondents. In the present research, we tackle the issue by incorporating attributes for the handling of specific waste categories (plastic, bio-waste, and hazardous waste) and by specifying how long it would take for respondents to carry out a particular home sorting system (in minutes per week). Findings from the present research indicate that households have different preferences towards the sorting arrangements of specific waste fractions. Nevertheless, in general we found that the longer the time it requires to implement a sorting system the less likely a household is going to choose a given sorting scheme.

Frequency of waste collection has been considered an important factor that determines the rate of home waste sorting. Based on a study on waste separation services in Beijing, Yuan and Yabe (2015) presented two levels of waste collection frequency: once per day and twice per week in their survey. Karousakis and Birol (2008) presented three levels of frequency of waste collection: fortnightly, weekly, and twice a week to their respondents. Czajkowski et al. (2017) specified the waste collection frequency as categorical attribute with three levels: once a month (as reference level), twice a month, and four times a month. Yuan and Yabe (2015) and Karousakis and Birol (2008) treated waste collection as a linear variable in their model specification and found that their respondents prefer more frequent waste collection. The findings from Czajkowski et al. (2017) also indicate that their respondents gain utility from more frequent waste collection. In the present study, based on the LCM, the frequency of waste collection attribute is only statistically significant for one of the four segments. Furthermore, contrary to findings reported from previous studies, the present research indicates that one segment of the respondents in our study actually prefers less frequent waste collection. Nonetheless, in our choice experiment, while the attribute for waste collection frequency is also categorical with three levels, the level specification is slightly different from that of Czajkowski et al. (2017). In our choice experiment, the levels are once every two weeks, once a week, and twice a week.

Based on the LCM, the households in our study can be grouped into four segments with regard to their home waste sorting preferences. Even if these four segments share similar responses towards selected features of home waste sorting alternatives (i.e. positive preference towards sorting plastic waste and negative reaction towards waste collection fee and time demand for sorting), the degree of the influence differs between segments. To illustrate, the average willingness to pay estimate for the option to sort plastic for 'the sorting enthusiastic' (S3) is 6 times as high as for 'the frequent waste collection resisters' (S1). This suggests that, compared with 'the frequent waste collection resisters' (S1), 'the sorting enthusiastic' (S3) has much higher preference for a waste sorting scenario with plastic separation.

The four segments can be further distinguished based on a number of factors. Households in segment 1 ('the frequent waste collection resisters' (S1)) prefer the existing arrangement for dropping off hazardous waste at a designated waste facility away from their residential areas. In addition, households in this segment appear to be very sensitive to how often waste collection takes place. Households in segment 2 ('the sceptics' (S2)) appear to be indifferent towards the option for local collection point for hazardous waste. Households in segment 3 ('the sorting enthusiastic' (S3)) – which have a majority of women - have positive preferences towards the possibility for disposing hazardous waste within close proximity to where they live and towards the requirement to sort plastic as well as bio-waste. Households in segment 4 ('the bio-waste sorting resisters' (S4)) are not very keen on the idea of having a local collection point for hazardous waste. They also demonstrate a negative preference towards bio-waste sorting. Using a probit model we have identified a range of household socio-demographic characteristics including gender, type of accommodation, and occupation as determinants of the heterogeneity of households' waste sorting preferences. To illustrate, female respondents, living in apartments and who are not currently studying are more likely to belong to 'the sorting enthusiastic' (S3). Additionally, our findings show that respondents' current habits on sorting and use of recycling facilities appear to be important predictors of waste sorting preferences for some segments. To illustrate, in our research, a higher frequency of use of a recycling centre is closely related to the likelihood of belonging to the 'frequent waste collection resisters' (S1), while the opposite relation is evident for the 'the sorting enthusiastic' (S3).

Previous studies have discussed the significance of personal intrinsic motivation as well as social pressures in explaining household behaviours with regards to waste sorting and handling (Czajkowski et al., 2017; Lee et al., 2017; Heller and Vatn, 2017). In the present research, the aforementioned attitudinal factors were found statistically significant in explaining household preferences for alternative waste sorting schemes. For 'the frequent waste collection resisters' (S1), in general the preference towards waste sorting by households in this segment has positive association with their internal motivation i.e. being self-conscious about the need for waste sorting. The opposite trend of association between personal motivation and waste sorting behaviours is evident for two segments - 'the sceptics' (S2) and 'the bio-waste sorting resisters' (S4). Furthermore, our findings also show that the role of social pressures is only statistically significant and negative in explaining the preference of only one segment - 'the sceptics' (S2). For the 'sorting enthusiastic' (S3), their waste sorting behaviour does not appear to be dictated by external motivation; as indicated by the statistically significant and negative relation between belonging to segment 3 and agreement with the importance of collective effort to handle waste sorting with neighbours.

In the present research, we are able to derive the implied value of time that reflects variation in household preferences for home sorting. We estimate the implied value of time for each of the four segments based on the corresponding parameter estimates for time attribute and annual bill for waste collection attribute. We found that 'the bio-waste sorting resisters' (S4) has the highest implied value of time of 46.69 DKK (6.28 EUR) per hour while 'the frequent waste collection resisters' (S1) has the lowest implied value of time of 20.72 DKK (2.78 EUR) per hour. Meanwhile the implied values of time for 'the sceptics' (S2) and 'the sorting enthusiastic' (S3) are 35.15 DKK (4.72 EUR) and 31.32 DKK (4.21 EUR) respectively. It is noteworthy that even the highest implied value of time of 47 DKK (6.3 EUR) per hour is still lower than the minimum wage for Denmark of approximately 110 DKK (14.8 EUR) per hour. The results indicate that sorting waste at homes still incurs opportunity cost of time to households. At the same time, the finding also suggests that the value of time for pro-environmental activities such as home waste sorting is not necessarily comparable to wage earning activities. Our finding is somewhat consistent with other studies albeit using a different approach. Bruvoll and Nyborg (2002), Bartelings and Sterner , 1999, Berglund (2006) reported respondents' willingness to pay for having others to sort waste being substantially lower than the average wage rate. Huhtala (2010) estimated the 'time cost' for recycling efforts by assuming the value of spare time at half of the wage rate. Literature from other fields, such as transportation studies, also points out that the value of leisure time is different from the wage rate (e.g. Jara-Díaz et al., 2008). Directly comparing the opportunity cost of time for household waste sorting derived from this study with those reported by earlier studies is rather problematic. This is partly due to the fact that the other studies were undertaken using different methodological approaches and adopted different assumptions with regard to the appropriate value of time for waste sorting or recycling activities. Our research, to the best of our knowledge, is the first attempt to explicitly capture the opportunity cost of time associated with waste separation at household level.

All in all, the present research shows that, although in general Danish households are supportive of a home waste separation program, their preferences for participation are heterogeneous and are influenced by a wide range of factors. For example, some households are not keen on sorting bio-waste and are very critical about how much effort they

have to put into sorting activities ('the bio-waste sorting resisters' (S2)). For these households, the opportunity cost of time hence the inconvenience cost of household waste sorting is high. Meanwhile, other households are enthusiastic to sort different categories of waste including bio-waste, however they are the only segment in favour of the proposed provision of local collection points for hazardous waste. As such, for households belonging to this segment – 'the sorting enthusiastic' (S3), the existing system requiring households to drop off certain categories of waste (such as hazardous waste) to a designated facility, which is typically located away from residential areas, seems to be sub optimal. Furthermore, being convinced that their efforts for sorting is worthwhile (as indicated by the proportion of waste getting recirculated to the economy) is important, the effects appear to be more pronounced on some groups ('the sceptics' (S2) and 'the bio-waste sorting resisters' (S4)).

It is important to acknowledge a caveat that financially less affluent and less educated households are slightly underrepresented in our sample survey. These households may display waste sorting preferences that are different from those households with higher education and income level. Nevertheless, the findings from the present research indicate the need to consider household heterogeneous preferences towards different sorting levels when policy makers or municipalities develop future planning for waste sorting programs for example in terms of rolling out new sorting systems or customizing current sorting policy. Findings from the present study can for example provide a basis for the development of campaign or outreach and flexible instruments to encourage household compliance on waste sorting. There may be scope for allocating public expenditure to public education on recycling (Sidique et al., 2010b). At the very least, the findings provide indications for policy makers/municipalities, that specific mandatory sorting schemes are not likely to lead to 100% efficacy, as parts of the population may have negative utility associated to a specific scheme. This might lead to a certain category of waste actually ending up in a general waste bin for example.

6. Conclusion

The present research investigates to what extent different factors influence household preferences for different alternatives for waste sorting and handling at home. We employed a choice-experiment based survey targeting households across Denmark and obtained 1011 complete responses for choice modelling. Findings from the research offers further insight into the scientific understanding surrounding the scope for getting households on board with home sorting. More specifically the research sheds further light on three areas. Firstly, previous studies refer to the number of categories of waste to sort as an attribute to depict how demanding the different home waste sorting schemes would be to the respondents. In our research, we approach the subject matter by presenting scenarios in terms of how the respondents are expected to handle specific types of waste (i.e. plastic, bio-waste, and hazardous waste). In addition we include an attribute for the expected amount of time as a proxy for the intensity of effort the respondents will have to devote on a weekly basis should they choose a specific home waste sorting system. Secondly, by having time and waste collection fee attributes in the choice set ups, we are able to approximate the implied value of time respondents ascribe on home sorting. Our findings indicate that the values range between 21 and 47 DKK (2.8 to 6.3 EUR) per hour, which is only a fraction of the minimum wage for Denmark of approximately DKK 110 (14.8 EUR). This shows that home sorting actually incurs opportunity cost of time to households. However, the value of time for pro-environmental activities such as home waste sorting cannot be directly estimated from wage earning activities. Thirdly, with the relatively large size of the sample in our study (1011 households) we were able to model the heterogeneity of preferences among the respondents with regard to different options of home waste sorting. Using the Latent Class Choice Model, we found that the respondents could be differentiated into four groups reflecting their unique preferences for home waste sorting. The heterogeneity in their preferences is particularly related to how households in each of these four segments respond to the following factors: the option to have a local collection point for hazardous waste, the requirement to sort bio-waste, and the frequency of waste collection. We also found that the segmentation of the households hence the heterogeneity in household preferences for home waste sorting is to a certain extent related to the sociodemographic characteristics of the respondents including gender, occupation, and the type of housing where respondents reside. Moreover, respondents' current level of waste sorting effort as well as personal motivation and social influence were found to be important predictors of some segments. Overall findings from the present research suggest that household preferences for home waste sorting and handling are not homogeneous. Households express different appreciations towards different aspects of home waste sorting systems. This needs to be considered in the development of policy initiatives for more effective sorting systems and more support from the public at large as manifested through greater compliance.

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Appendix 1. Marginal effects of probit analysis: sociodemographic and attitudinal determinants of segmentation of household waste sorting preferences

Variables	Marginal effect			
	Segment 1 – 'the frequent waste collection resisters' (S1)	Segment 2 – 'the sceptics' (S2)	Segment 3 – 'the sorting enthusiastic' (S3)	Segment 4 – 'the bio-waste sorting resisters' (S4)
Gender (Female = 1)	na	−0.0665*** (0.0247)	0.0681*** (0.0245)	na
Student (Yes = 1)	na	na	−0.1066** (0.0474)	na
White collar (non-managerial) (Yes = 1)	na	na	na	−0.0803** (0.0336)
Apartment (Yes = 1)	na	na	0.0685** (0.0286)	na
Villa/single-family house (Yes = 1)	na	0.0668** (0.0276)	na	na
Region Midtjylland	0.0762 (0.0407) (ns)	na	na	na

Current sorting effort (minutes per week)	na	na	na	0.0022*** (0.0008)
Use of recycling centre > 5 times a year (Yes = 1)	0.0955*** (0.0342)	−0.0565** (0.0275)	−0.0900*** (0.0278)	na
Sorting consciousness	0.1450*** (0.0352)	−0.0593** (0.0265)	na	−0.0955*** (0.0287)
Lifestyle for the environment	na	−0.0537** (0.0266)	na	na
Collective work	0.0703 (0.0357)(ns)	na	−0.0534** (0.0261)	na
My neighbours' judgement	na	−0.1138*** (0.0419)	na	na

Standard errors are reported in (parentheses).
ns = not statistically significant (p value > 0.05).
na = removed during stepwise estimation (*p* value > 0.1) hence not appear in the specification of the selected model.
*** Indicates significance at 1% level.
** Indicates significance at 5% level.

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