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The use of systems models to identify food waste drivers☆

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ABSTRACT

In developed countries, the largest share of food waste is produced at household level. Most studies on consumers' food waste use models that identify covariates as significant when in fact they may not be, particularly where these models use many variables. Here, using EU-level Eurobarometer data from 2013, we use alternative analytical methods that avoid these problems (Bayesian Networks) to identify the impact of household characteristics and other variables on self-assessed food waste. Our analysis confirmed that the country, the age of the respondent, the status (student/non-student), and a belief that the family wastes too much are related to the level of self-assessed food waste. But we found no evidence that waste behaviours differ between people living in urban and rural areas, and little support of a difference between genders. Households from lower-income EU countries (e.g. Portugal, Greece, Bulgaria, Cyprus and Latvia), as well as students and young adults tend to report higher levels of food waste. Hence, the adoption of an EU strategy based on the concept of subsidiarity, and of country-level policy measures targeting different age groups is suggested. Furthermore, our analysis shows that policy makers need to be wary of relying on analysis based on large datasets that do not control for false-positives, particularly when sample sizes are small.

1. Introduction

Food waste represents a major challenge for responsible business and consumer behaviours, and for sustainable food value chains (FAO, 2011, 2013). For this reason, the Sustainable Development Goal 12, Target 12.3 calls for halving per capita food waste and reducing food losses by 2030 (UNEP, 2016). Also the EU has made the reduction of food waste a priority (European Commission, 2015). The waste produced at household level is thought to be responsible for the largest proportion of all food wasted in developed countries (Parfitt et al., 2010). Stenmarck et al. (2016) estimated food waste in the 28 EU countries (extrapolated from data for 11 countries) at 87.6 ± 13.7 (95% CI) million tonnes, with 46.5 ± 4.4 (95% CI) million tonnes coming from households. This means that between 46.7% and 63.5% of the total EU food waste comes from households.

Food waste occurring at household level has multiple and interrelated drivers, with heterogeneous geographical and social impacts (Wenlock and Buss, 1977; Sonesson et al., 2005; Barr, 2007; Koivupuro et al., 2012; Canali et al., 2014; Parizeau et al., 2015; Stancu et al., 2016; Setti et al., 2016). Hence, the identification and the design of effective policy interventions requires the comprehension of this complexity using a systems approach (Godfray et al., 2010).

The current approaches for identifying the drivers of food waste to design targeted policy interventions generally rely on frequentist statistics (i.e. null hypothesis testing) (e.g. Quested and Luzecka, 2014; Secondi et al., 2015). However, null hypothesis testing does not provide the probability of the null hypothesis or of its alternative; hence, its usefulness to underpin decision making is limited (Claxton, 1997; Kileen, 2005). In addition, the utility or "value" of a decision or intervention cannot be estimated or identified using null hypothesis testing (Claxton, 1997). Assessments of food waste drivers using a regression framework often test multiple explanatory variables (Secondi et al., 2015; Stancu et al., 2016; Visschers et al., 2016). However, with an increased number of variables, the probability of Type I errors (i.e. false positives) increases. This, in combination with the problem of selective reporting and "researcher degrees of freedom" (i.e., the

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incomplete publication of the outcomes measured, or of the analyses performed; Simmons et al., 2011; Reid et al., 2015; see Fig. 5), which affects all scientific fields, implies that the actual drivers of household food waste cannot be reliably identified.

This represents a challenge for policy makers who may wish to use scientific papers as evidence to underpin robust policy decisions. Decision-analytic approaches may offer greater assistance to policy makers in situations where potential interventions are beset by complexity (Stewart et al., 2014). The processes of making decisions in the face of complexity and uncertainty have long been of academic interest; Bernoulli (in the 1700s) and Laplace (in the 1800s) addressed utility and probability in reference to decision making (Howard, 2007). These theoretical applications of decision theory were robustly applied to the real world during the Second World War (which led to the development of the modern language associated with systems models) (Howard, 2007). More recently, policy interventions in fields as diverse as public health (e.g. Nutt et al., 2010), sustainable energy (e.g. Wang et al., 2009) and natural resource management (e.g. Punt and Hilborn, 1997) have been explored using decision analysis.

Differently from null-hypothesis testing, decision-theoretic approaches look at a problem in a systemic way, addressing the net changes in the outcome (i.e. the variable) of interest, rather than arbitrary levels of statistical significance (i.e. there is no test of statistical significance). Importantly, decision-theoretic approaches explicitly (and mathematically) incorporate uncertainty, which highly characterizes the data used to underpin the decisions on addressing food waste.

Secondi et al. (2015) used data from the Eurobarometer Flash survey (388) "Attitudes of Europeans to waste management and resource efficiency" (European Commission, 2014) to identify the variables affecting food waste through a regression model (i.e. using frequentist statistics). Here, a similar but unique subset of the Eurobarometer dataset is used to identify the drivers of self-reported EU food waste, but it is analysed by means of a decision-theoretic approach. The reporting of the variable selection and statistical procedures in Secondi et al. (2015) were insufficient to replicate their study in full to allow a direct comparison of the two approaches. However, we demonstrate the potential for Type I error in a frequentist regression framework that does not account for model structural uncertainty. Our overarching goal is to highlight potential realms of interventions, and indicate which of them might help reduce food waste. As food waste is a complex issue, with many interrelated variables potentially affecting it, a systems model is used to assess it as a system in a probabilistic framework.

2. Material and methods

2.1. Dataset

The open-source Eurobarometer dataset is used. This dataset presents three main advantages: 1) it represents the largest survey on consumer attitudes to food waste in terms of sample size and geographical extent; 2) it registers the attitudes to food waste within the whole EU, thus capturing inter-country heterogeneity; 3) it represents a valid informative basis to support policy interventions under subsidiary schemes.

Eurobarometer Flash surveys were carried out through ad hoc thematic telephone interviews run at the request of the European Commission. The interviews used to build the dataset occurred in December 2013. Overall, 26,595 households were asked 20 questions on their attitudes and behaviours in relation to household food waste. Respondents were asked to estimate the amount of food purchased that goes to waste (see Table 1 for the categories). Additionally, demographic variables such as age, gender, nationality, age at which full-time education stopped, current occupation, location (urban, rural, etc.), phone ownership, and household composition (members aged 15

Table 1
Variables included in the dataset used within this paper.

Eurobarometer 388 question	Variable name	States
Q9: Can you estimate what percentage of food you buy goes to waste?	Food waste	More than 50 % 31 to 50 % 16 to 30 % 6 to 15 % 5 % or less None Did not answer
D3a: What is your nationality? Please tell me the country(ies) that applies(y).	Country	Austria Belgium Bulgaria Croatia Cyprus (Republic) Czech Republic Denmark Estonia Finland France Germany Greece Hungary Ireland Italy Latvia Lithuania Luxembourg Malta Poland Portugal Romania Slovakia Slovenia Spain Sweden The Netherlands United Kingdom
D2: Gender	Gender	Male Female
Q3 Which of the following actions do you think would make the biggest difference in how efficiently we use resources? Reducing waste at home.	Home waste	Yes No
Q17: How much litter is there in the area where you live (litter on the street, in natural surroundings, etc.)?	Litter	Quite a lot A lot None Not much Don't know
Q6 Do you sort the following types of waste, at least occasionally? Kitchen waste.	Kitchen waste	Yes No
D4: How old were you when you stopped full-time education?	Education	Still Studying Up to 15 16-19 20 years and older No full-time education Don't know Refusal
D5: As far as your current occupation is concerned, would you say you are self-employed, an employee, a manual worker or would you say that you are without a professional activity?	Employ	Employees Manual workers Not working Refusal Self-employed
D1.1 How old are you?	Age	15 - 24 years 25 - 34 years 35 - 44 years 45 - 54 years 55 - 64 years 65 years and older Refused to answer

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