

Article

Consumers' Perspective on Circular Economy Strategy for Reducing Food Waste

Massimiliano Borrello ¹, Francesco Caracciolo ¹, Alessia Lombardi ¹, Stefano Pascucci ^{2,*} and Luigi Cembalo ¹

¹ Department of Agricultural Sciences, University of Naples Federico II, Via Università 100, 80055 Portici, Italy; massimiliano.borrello@unina.it (M.B.); francesco.caracciolo@unina.it (F.C.); alessia.lombardi@unina.it (A.L.); cembalo@unina.it (L.C.)

² Business School, University of Exeter, Penryn Campus, G16 The SERSF Building, Penryn, Cornwall TR10 9EZ, UK

* Correspondence: s.pascucci@exeter.ac.uk

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Abstract: The current linear system of production and consumption is unsustainable. In the food sector, despite the fact that valuable natural resources are intensively used to produce and distribute food products, little is done to upcycle residues generated along the supply chain. Circular economy strategies are crucial for restructuring the take-make-dispose model through the active participation of all actors of supply chains. However, little is known about consumers' willingness to participate in circular economy. A structured questionnaire was submitted to a representative sample of Italian households to assess the willingness of consumers to be actively involved in closed loops aiming at reducing food waste. Consumers are involved by returning their organic food waste to retailers in exchange for discounts on the purchase of animal products. The organic food waste returned enters in the production process of animal products. A choice experiment was designed to analyse alternative programs. Two scenarios were presented: one with a traditional technology (composting), and a second one with a radically innovative technology (insects as feed). Preferences and trade-offs, in monetary terms, among attributes were computed. Results depict a comprehensive portrait of the potential participation of consumers to closed loops inspired by the principles of circular economy.

Keywords: radical innovation; insects as feed; recycling; food sector

1. Introduction

Our post-industrial society is facing alarming global issues caused by the impacts of human activities on the environment. This calls for re-thinking the way we organise our economic and social relations, which currently seem locked within traditional technologies, life styles, supply chains, as well as organizational, regulatory, institutional and political structures [1]. The possibility to change entails the development of innovative strategies for transition to sustainability. According to Markard et al. [1], “sustainability transitions are long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption”. Such transformations are radical and should be grounded on the investigation of the interdependence and co-evolution of economies and natural ecosystems over time and space. This investigation calls into question the established mainstream economy which has been defined as a systematically linear structure in which natural resources follow a “cradle to grave” flow (e.g., [2,3]). Materials are extracted; they are used to produce goods; these goods are sold to customers; and eventually costumers dispose of the goods (or of their residues) at their end-life. Along this flow, namely the supply chain, waste and pollutants are produced, and huge amounts of

materials that could be reused or recycled got lost, mainly landfilled. Since this system exceeds the capacity of our planet to regenerate resources and to absorb waste and pollutants, it is not bound to endure [4].

A sustainable economic system should instead try to emulate natural processes of the biosphere, according to the concept of bio-mimicry [5]. Biological materials move within ecosystems following continuous circular flows of matter and energy in which the idea of waste is not contemplated. To illustrate, dead leaves of a tree are decomposed and transformed into minerals that feed the tree for producing new leaves. This process is indeed circular. Circular economy is aimed to replace traditional linear supply chains with networks in which materials are recycled within production systems grounded on the principle “waste = food” [6,7]. This principle reinforces the common idea of recycling towards the upcycling [8], that refers to any process able to transform waste into higher value products by making them the input for other products. To summarise, circular economy is planned in order to make “someone’s waste the resource of someone else” [7,9]. Therefore, a circular economy approach can foster more radical transformations and stimulate radical innovation able to integrate human activities into ecosystems [10]. For example, new circular economy models might attempt to capitalise on waste produced during linear life cycles. The need of shifting towards a circular economy has already been introduced in the agenda of international policy makers [11] and becoming part of the strategic plans of established businesses and industries [6]. However, in order to make a shift toward circular economy a transition to sustainability, several challenges still need to be faced by the actors engaged in this transformation [9]. Some of these challenges concern society and, more specifically, the role of consumers. In the linear economy, consumers are the last link of supply chains. Their participation is confined to the mere purchase of products, as well as to the compliance to the rules of planned and perceived obsolescence [12,13]. Thereby, they are passive and unaware in their condition of intermediaries between retailers and waste collection. Even though there are examples of final users (consumers) eventually actively involved in process innovation, it is a peculiarity of circular economy to engage consumers, as well as all the other actors of supply chains, in an active participation for the recycling of materials [14,15]. Among materials through which consumers could participate to circular economy, food waste is one of the more concerning in terms of amounts produced [15,16]. Wastages generated during late stages of food supply chains, namely during marketing and consumption, are considered food waste [17]. Consumers in food insecure countries are often careful to not waste food. Therefore, food waste is a peculiar practice of Western countries, where it is often associated to “behavioural” causes [18].

In this domain, consumer behaviour gives a dramatic contribution to the food waste produced in developed countries [19]. Where abundance makes people able to afford wasting food, consumers deliberately choose to discard food still edible. Some of the waste produced arises from food that is not edible, such as meat bones or egg shells (“unavoidable food waste”). Some waste derives from food that some people eat and others do not, such as bread crusts, or that can be eaten when a food is prepared in one way but not in another, such as potato skins (“possible avoidable” food waste). However, households throw away huge amount of food that was, at some point prior to disposal, perfectly edible (“avoidable food” waste) [20]. The latter amount is generated by a set of inefficiencies in the management of households’ flows of food items. A proper planning of both food purchase and preservation is not trivial task. Common behaviour is buying more food than is necessary and then giving little attention to food spoilage. Even when consumers try to follow indications of producers, 20% of food is thrown away because of the confusion generated by the dates on product labelling [21]. In addition, a number of constraints concerning the domestic sphere prevent the rational management of pantries (e.g., different food habits among family components, and unexpected social events). Since circular supply chain models, or so-called closed loops, could be a method to reduce food waste from its present high levels [17,22,23], consumers could contribute by returning their household food waste to retailers to let it re-circulate, or by purchasing circular food products. This kind of active consumer participation is consistent with the increasing trend of consumers engaged in alternative food

chains [24]. Furthermore, the implementation of closed loop systems involving consumers would ride the wave of the change in consumers' attitudes towards a sustainable lifestyle [25]. However, facing the consumers' side of circular economy is still challenging [15]. Circular economy assumes that consumers can deal with household recycling of materials. They should change their behaviour regarding the end-life of products by collecting their waste in order to return it to producer/retailers. Putting aside these materials and taking them back to their source requires an effort involving commitment and responsibility [15]. Furthermore, consumers should deal with new technologies used for recycling biological materials and closing the loop of food waste. Circular economy implies new strategies aimed to recycle materials through the use of innovative solutions and technologies [14]. Different strategies can be implemented to recover nutrients from food waste and at different stage of the supply chain. An example is represented by high added-value components—recovered from food waste and suited to food industry—which can be extracted by means of new emerging technologies [26]. However, these technologies do not rely on consumers' participation. Instead, to tackle food waste issues at consumption stage it requires actively engaging with consumer's decision making and strategies related to food purchasing and disposal [15]. To foster innovative solutions, seeking the participation of consumers may produce terrific results, since the magnitude of change it can produce can be substantial. However, combining innovative solutions with consumers' participation is challenging since acceptance of novel technologies associated to food products is often very low, and in general the attitude of consumers to change their food habits is also limited [27]. Consumers are not only reluctant to change their own food habits, but they are very sensitive to any form of technological development associated with food products [28], and deeply conditioned by the cultural significance often associated to food products [29,30]. Economic and psycho-behavioural factors, such as risk aversion, lack of control over the new technology, status quo bias, difficulty to perceive benefits, as well as perception of unnaturalness, are among the causes of consumers' aversion towards novel technologies related to food [27]. The perceived naturalness, meant as the production of food without the use of modern technologies, is an attribute highly appreciated by consumers. Consumers also seem to overestimate the risk of unknown food technologies they are not familiar with, whose benefits are unclear, and whose consequences are not perceived under their control. The perceived loss generated by this risk makes people attached to the status quo, whatever it is the possible advantage generated by the adoption of the technology at hand. Therefore, if innovative solutions to reduce food waste can be found by closing loops with the participation of final consumers, the design of such a circular strategy should start from a careful assessment of the consumers' willingness to engage in and accept different innovation pathways.

This study aims at carrying out a first assessment regarding the participation of consumers to circular agri-food loops to reduce food waste. To the best of our knowledge, no studies have explored so far the consumers' perspective on innovations related to circular economy. The implementation of innovative solutions, to reduce food waste follows conceptually the need of establishing the circular economy. Thereby, we approached our research questions according to this sequence. First, our purpose was to assess consumers' willingness to participate in strategies to reduce food waste inspired by the design principles of the circular economy. Second, through the design of two different scenarios, we explored how consumers' willingness to participate is conditioned by the type of innovative technological solution suggested and, namely, whether the food waste loop is closed through a more conventional composting technology or using insect breeding practices. A questionnaire was administered to a representative sample of Italian households (1270 interviewees). We designed a hypothetical strategy of reduction of food waste which consumers to take back their food waste to retailers through the participation in a food waste recycling initiative. This participation mechanism is based on an agreement between a consumer and a retailer. In a choice experiment, grounded on an efficient experimental design, respondents were asked to choose between alternative initiatives with varying attribute levels. The paper is organised as follows. First, we present the framing used to conceptualise innovative solutions designed to reduce food waste. Then, we present

the methodology and data section. Results are presented in Section 4 while in Section 5 we engage in a more in-depth discussion and provide concluding remarks.

2. Framing of Innovative Solutions for Reducing Food Waste

Circular economy tries to update the basic practice of recycling materials within natural ecosystems. To do this, it introduces the concept of cascading, namely the diversified use of materials through consecutive production processes [6,7,14]. Cascading happens by means of networks of factories in which organic by-products, instead of being landfilled or directly returned to the soil, are used as inputs of new products. Thereby, food waste can become the substrate for feeding bio-refineries [31,32], where biological materials are converted by degrees into bio-chemicals, plastics, medicines and fuel through cascading processes. Among the alternatives for extracting the maximum value from food waste, the idea of making it re-circulate within food supply chains is fascinating. In this way, the ancient concept of soil restoration by returning food residues to the soil is updated with the use of food waste as input for the agri-food industry. To illustrate, food waste may be used as feed for livestock and fish [33,34], as human food [35], as well as for the production of fertilizers [36,37]. For the purposes of this study, a traditional technology, namely composting, and another that is radically innovative, namely insects as animal feed, were compared in order to investigate the contribution of the acceptance of novel technologies to consumers' perception of the circular economy.

Composting is the production process of compost, the soil-like material generated through the aerobic decomposition of organic matter by organisms like bacteria, fungi, insects and earthworms. Since the usefulness of this process for generating stable products [38], worldwide interest in using composting for recycling municipal solid waste is growing. Unlike the spread diffusion of composting, insect farming is a radically innovative method for recycling food waste. Insects are able to feed on any organic material [39]. More specifically, *saprophagous* insects can feed on decaying organic matter and perform an essential role for the biosphere by contributing to the recycling of nutrients. In this field, satisfactory results about the possibility of breeding insects on organic substrates and organic waste have already been obtained [40,41]. Furthermore, insects are able to convert embedded energy of decaying matter into complex organic molecules like proteins, suited to be fed to livestock and fish. In order to produce high value edible proteins within the framework of the circular economy, insects would allow to bypass biodegradation and production of vegetal proteins through the photosynthesis. Along this line, Premalatha et al. [42] sharply affirm: it is a "supreme irony" that huge amounts of money are "spent every year to save crops that contain no more than 14% of plant protein by killing another food source (insects) that may contain up to 75% of high-quality animal protein". Hence, starting from the idea that many kinds of insects are already part of the natural diet of farmed animals like chickens, pigs and fish [39], studies about the performances of this practice in the field of livestock studies have been arousing the interest of researchers in the last fifty years [43,44]. This interest is also grounded on the fact that the main insect species suited for recycling waste are among those used to produce animal feed [45]. Furthermore, international public institutions have been claiming the importance of insects to reduce the environmental impact of the livestock sector [46]. Thereby, business ventures are already farming insects to produce animal proteins from the recycling of materials generated from food supply chains. However, other than general aversion of consumers regarding novel food technologies, in the case of insects, an additional criticism concerns strong socio-cultural barriers [47]. Insects are associated with their impact as vectors of diseases, as crop pests, as well as parasites of stored products. Furthermore, in Western countries, repulsion and disgust are the typical attitudes towards insects [48]. Consequently, even if there is "a positive atmosphere and momentum" [49] for the acceptance of insects as a new ingredient in animal feed, socio-cultural barriers could still limit their use for the recycling of food waste in the field of the circular economy [15].

3. Data and Methods

3.1. The Survey and the Experimental Design

A choice-based conjoint experiment (Figure 1) for a representative sample of 1270 Italian households (18–65 years old with balanced geographic distribution) was developed in order to: (i) assess consumers' willingness to be actively involved in a circular economy framework; and (ii) investigate the effect on consumers' choices of introducing a radical innovation related to a technology implemented in closed loops. Data were collected through a structured questionnaire submitted through GfK, a global company that performs market and consumer studies. GfK is the fourth largest market research organisation in the world. It assures the representativeness of the data according to the following criteria: geographical, size of the city, number of households members, gender, age, education, occupation and class of income. Consumers who responded to our questionnaire were GfK panellists. GfK panellists use a specific hardware (an ad hoc customized tablet) for compiling the survey.

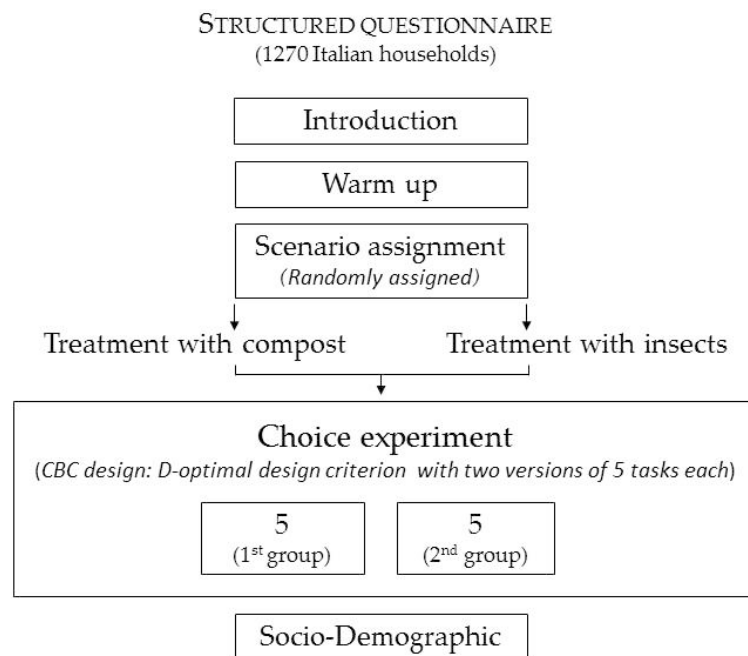


Figure 1. Data collection process.

The core of the survey concerned the investigation of consumers' preferences for a program regulating the participation to a hypothetical food closed loop, which implied the restitution of household organic food waste. Within each household, the person responsible for the purchasing was selected for responding to the survey. Consumers were informed that their organic food waste would have been used for the production of animal products. These products would have been sold at the same retail shop where consumers should have returned their waste. The choice experiment was aimed to analyse attributes of a program between consumers and the retailer. The questionnaire started with a clear explanation of the main features of the circular economy to introduce the topic of the survey. The concept "waste = food" was explained to highlight the relevance of circular production for reducing waste (Appendix A). The questionnaire was organised in three sections.

The first section, the so-called warm-up, included questions aiming to understand whether interviewees were involved in household activities regarding food purchase and waste management.

In the second section, one scenario among the two developed (composting or insects as animal feed) was randomly proposed to interviewees. Subsequently, respondents were divided in two groups

to whom were administered one of the two series of five choice tasks as developed by means of a randomised choice-based conjoint (CBC) design approach with complete enumeration computed by Sawtooth Software version 2 (Sawtooth Software, Sequim, WA, USA, 1999) [50]. Respondents were asked to perform a choice task between two alternative combinations of attribute levels (Table 1). The attributes and their levels were selected according to rational criteria based on: (i) possible influence of the attribute/level on consumers' willingness to participate; (ii) consistency with common households' routines; and (iii) plausibility of the presence of the attribute/level within a program of participation. A monetary reward for the participation to the program, by means of a monthly fixed discount for the purchase of animal products derived from the closed loop described, was assumed to be influential to consumers. It is worth pointing out that discounts could induce growing consumption of animal products, thus generating a negative backfire effect on the environment. However, the reduction on the price of animal products is not conceived theoretically as a discount. Instead, it is a reward which consumers receive for their participation to a programme aimed to have positive effects on the environment. We assume that consumers interested to this cause would not misuse this reward for personal advantage. The correlation between households' income and food consumption is a matter of fact, but in this case we do not believe that the reward proposed in the experiment would be sufficient to modify the quantity of animal products consumed by households.

Table 1. Selected attributes and levels of proposed programs.

| Attributes | Levels Definition |
|--|---|
| Monthly fixed discount | From €5 to €25, with €5 intervals |
| Frequency of the delivery of organic waste | Number of deliveries of organic waste per week (once or twice a week) |
| Modality of the delivery of organic waste | Presence or absence of the collection at home of the organic waste |
| Duration of the participation to the program | From 6 months to 12 months |
| Penalization for the delivery of non-organic waste | Presence or absence of a reduction of the discount |

The levels of this attribute were calculated as percentages (from 2.5% to 12.5%) of an estimation of the expense for animal proteins of the average Italian family based on national statistics referred to the year 2014 [51]. The problem of assuring the proper sorting by consumers of the organic food waste was dealt by including among the attributes a penalization on the discount for the delivery of non-organic waste. The frequency of the delivery of the organic waste was assumed to be once or twice a week, according to the frequency that is commonly observed for the collection of this type of waste by curbside recycling services. Regarding the duration of the program, a mediation between the need of having a lasting loyalty of consumers and the risk of scaring them with a much too onerous commitment was adopted. Other than the frequency and the duration, the grade of commitment to the program was described through the modality of the participation, namely whether or not there was a benefit in a home collection service which relieved consumers from the effort of personally delivering the organic food waste to the supermarket. To the best of our knowledge, programs like the one of this research have never been studied or implemented so far; therefore, neither literature nor similar programs were available when the experiment was set. Criteria to select attribute and levels were chosen after having consulted a panel of experts and consumers.

Each alternative combination of attribute levels represents a programme generated according to the CBC design. In randomized CBC designs, each attribute level is equally likely to be included with each level of every other attribute. The complete enumeration assures that profiles are as nearly orthogonal as possible within households, and the frequencies of level combinations between attributes are equally balanced. The D-optimal coefficient of the experimental design resulted equal to 0.923. Interviewees had the possibility to choose the most preferred programme or to choose none of them.

Scenarios were introduced with a general explanation of circular economy and closed loops applied to agri-food system. Then, a detailed description of the hypothetical closed loop was provided. As mentioned earlier, two scenarios were randomly assigned to respondents so that two groups were generated; the two groups do not show significant differences on the socio-economic variables according the results of Hotelling's T-squared means test (F test statistic: 0.134). To the first group was presented a closed loop in which composting is used (Figure 2). In this loop, compost is meant to be a fertilizer to cultivate fodder crops for livestock and fish. To the second group was presented a closed loop that included the use of insects as animal feed (Figure 3) (Appendix A).

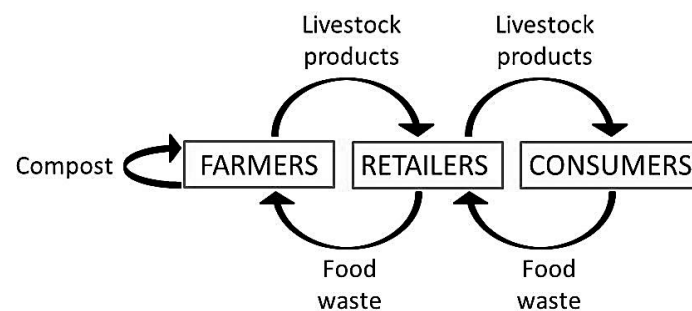


Figure 2. Circular loops concerning the use of the technology “compost” for recycling household food waste.

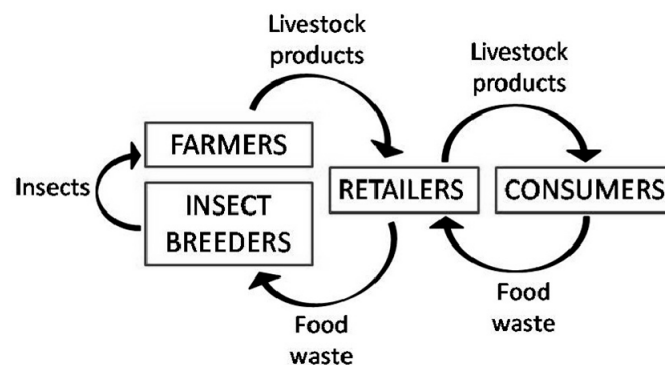


Figure 3. Circular loops concerning the use of the technology “insects as feed” for recycling household food waste.

Interviewees were informed that their participation to the programme would have implied the restitution to retailers of an amount of organic food waste proportionate to the number of the family members. In return, they would receive vouchers (discounts) for the purchase of animal products whose production process entails the use of the organic food waste returned. These products were eggs, pork, chicken, fresh farmed fish (salmon, sea-bass and sea-bream). Products were chosen since insects are part of the natural diet of the animals raised for the production of these products. The use of insects in the diet of farmed fish is already allowed by law, while it may be allowed in the near future for chickens and pigs. We chose these products also according to their degree of spread. The selected attributes, which in different level combinations formed the different programme types proposed in the choice tasks, were accurately described so that respondents could make an informed choice. The choice tasks were finally introduced highlighting that they represented hypothetical but realistic programmes that could be offered in the future from Italian retailers. In the third section, participants were asked to answer questions regarding their social, economic and demographic conditions.

3.2. Descriptive Statistics of the Sample

The questionnaire was submitted to a representative sample of 1270 Italian Households. Interviewees' social, economic and demographic conditions collected were age, gender, household size, household role, education level, geographic origin, city size, socio-economic conditions. They were also asked if they are used to separate and dispose organic waste (Table 2). Respondents (202 males and 1068 females) were in the age range 21–65 years (47 ± 10) and living in middle-class (52.4%) medium-size households (3.13 ± 1.2 members). Most respondents (92.7%) were the head of the family—or his (her) wife (husband). About a quarter of respondents held a university degree (24.33%). The sample was balanced according to the population distribution of Italy so that almost half of the respondents belonged to the north of the country (48.7%), followed by the south and the islands (35.4%) and then by the centre (15.9%). As regards the city size, no categories prevailed noticeably. However, more than 45% of respondents belonged to medium size cities (categories 3 and 4). The questionnaire also revealed that a high percentage of the sample (88%) already sorts their household organic food waste (also known as humid waste).

Table 2. Descriptive statistics of consumers interviewed.

| | Description | Mean | Std.dev | Min | Max |
|------------------------|---|--------|---------|-----|-----|
| Age | (year) | 46.87 | 9.916 | 21 | 65 |
| Gender | 1 if female 0 otherwise | 0.841 | | 0 | 1 |
| Household size | | 3.135 | 1.198 | 1 | 9 |
| Household role | | | | | |
| | Head of the family (or spouse) | 92.7% | | | |
| | Son/daughter | 6.7% | | | |
| | Others | 0.6% | | | |
| Education level | | 2.93 | 0.786 | 1 | 4 |
| | 1 primary | 3.31% | | | |
| | 2 secondary | 24.57% | | | |
| | 3 high school | 47.80% | | | |
| | 4 university | 24.33% | | | |
| Geographic origin | | | | | |
| | North | 48.7% | | | |
| | Centre | 15.9% | | | |
| | South and islands | 35.4% | | | |
| City size | | 3.29 | 1.568 | 1 | 6 |
| | 1 less than 5000 inhabitants | 17.64% | | | |
| | 2 more than 5000 and less than 10,000 | 14.17% | | | |
| | 3 more than 10,000 and less than 30,000 | 23.54% | | | |
| | 4 more than 30,000 and less than 100,000 | 21.97% | | | |
| | 5 more than 100,000 and less than 500,000 | 11.34% | | | |
| | 6 more than 500,000 inhabitants | 11.34% | | | |
| Socio-economic classes | | 3.37 | 1.068 | 1 | 6 |
| | 1 lower class | 9.38% | | | |
| | 2 working class | 10.01% | | | |
| | 3 lower middle class | 21.91% | | | |
| | 4 middle class | 52.40% | | | |
| | 5 upper middle class | 5.83% | | | |
| | 6 upper class | 0.47% | | | |
| Humid waste | 1 if already sorting organic waste; 0 otherwise | 0.88 | | 0 | 1 |

3.3. Empirical Model

The empirical framework adopted has its theoretical foundations in the random utility theory (RUM) of McFadden [52]. It follows previous studies that analyse preferences for contract attributes such as Roe et al. [53] and Cembalo et al. [54] amongst others. The framework supposes that when J programme alternatives are showed to the i -th consumer, the utility assigned by the consumer to each j -th programme alternative is a linear, additive, and separable function of all c -th attributes that constitutes the contract:

$$U^i_j = f(x_j)^i + \varepsilon^i_j \quad (1)$$

where x_j is a vector of observed attributes characterizing the j -contract.

In RUM, the programme alternative chosen j represents the outcome of an expected utility maximization exercise of the household. The random utility model considers utility U^i_j equal to the sum of an observable component Bx_j and the stochastic component ε_j , with B as vector of unknown parameters that could be assumed constant (fixed parameter model) or varying (random parameter model) across consumers (Equation (2)).

$$U^i_j = Bx_j + \varepsilon^i_j \quad (2)$$

In the latter case, distribution of each B^i may follow a probability distribution function. Generally, it is distributed as normal, $N(\tau, \sigma^2)$, relaxing the i.i.d. assumption on the error terms [55] while standard errors are clustered by households to take into account the correlation among residuals. Estimates of B parameters can be obtained through the maximum likelihood estimator [55], with τ indicating the mean value of the distribution function of the parameter. The greater the value of τ , the greater will be the preference for the consumers for that attribute of the contract (if statistically significant). Estimates of σ^2 show the variability of the preferences toward each contract attribute across the consumers.

4. Results

Table 3 shows the number of consumers that refused to participate in both programmes for the five choice tasks. A high percentage of interviewees (78.9%) accepted participating in one of the two programmes for all choice tasks, whereas only 6.61% of respondents accepted none. Our outcomes show that the treatment on the use of the technology (“compost” vs. “insects as feed”) had very scarce effect on the choices of respondents. The percentage of consumers who refused to participate in both programmes is similar for the treatment with compost and for the one with insects (second and fourth column of Table 3). Treatments had no influence on the factors of the participation, so they likely did not influence the point of view of consumers about the programmes. This result supports the idea that consumers’ willingness to participate to a closed loop does not depend significantly on the level of innovativeness of the employed technology.

Table 3. Respondents who rejected both programmes.

| Number of Refusal | Treatment with Compost | | Treatment with Insects | | Total | |
|-------------------|------------------------|------------|------------------------|------------|-------|------------|
| | Value | Percentage | Value | Percentage | Value | Percentage |
| 0 | 429 | 79.59 | 573 | 78.39 | 1002 | 78.90 |
| 1 | 27 | 5.01 | 44 | 6.02 | 71 | 5.59 |
| 2 | 26 | 4.82 | 26 | 3.56 | 52 | 4.09 |
| 3 | 14 | 2.6 | 23 | 3.15 | 37 | 2.91 |
| 4 | 7 | 1.3 | 17 | 2.33 | 24 | 1.89 |
| 5 | 36 | 6.68 | 48 | 6.57 | 84 | 6.61 |
| | 539 | | 731 | | 1270 | |

The effects of programme attributes on the consumers’ willingness to participate to a circular economy have been estimated with a conditional logit model with both random and fixed parameters. Results are reported in Table 4.

According to the model results, the only programme attribute consumers did not consider in their choices is the duration of the participation to the programme. The coefficient is indeed not statistically significant. The model also provides statistical evidence that consumers clearly prefer a high discount, low frequency, the absence of a penalization and the presence of the collection at home of the organic food waste.

From these results, some indications, in monetary terms, can be obtained on the trade-off consumers’ made between the attributes and the discount (third column of Table 4). Parameter estimates obtained by the conditional logit can be used to calculate marginal WTP estimates, which are

computed as the negative ratio between the c -th attribute-level coefficient and the coefficient measured in monetary terms that is in our case the one related to the discount ([56,57], Equation (3)).

$$WTP_c = -\text{Coeff.}_c / \text{Coeff.}_{\text{discount}} \quad (3)$$

The modality of the delivering of organic waste has a discount premium estimated equal to €9.84 per month for receiving the service of collection at home. Delivering the organic food waste with a higher frequency and having a penalization for the delivery of non-organic food waste are considered by consumers as a loss. Thereby, consumers would ask an additional discount of €2.12 for delivering food waste twice a week and an additional discount of €2.39 for subscribing to a programme with the penalization.

Table 4. Conditional logit results.

| | Fixed Parameters | | | Random Parameters | | | |
|--------------|------------------|------------|------|-------------------|------------|---------------------|------------|
| | Coeff. | p -Value | WTP | Coeff. (τ) | p -Value | Coeff. (σ) | p -Value |
| Discount | 0.096 | 0 | 1 | 0.141 | 0 | 0.095 | 0 |
| Frequency | −0.204 | 0 | −2.1 | −0.469 | 0 | 2.271 | 0 |
| Modality | 0.948 | 0 | 9.84 | 1.447 | 0 | 2.338 | 0 |
| Duration | −0.013 | 0.732 | −0.1 | −0.026 | 0.649 | | |
| Penalization | −0.23 | 0 | −2.4 | −0.567 | 0 | 1.421 | 0 |
| Opt out | 0.184 | 0.012 | | 0.762 | 0 | | |

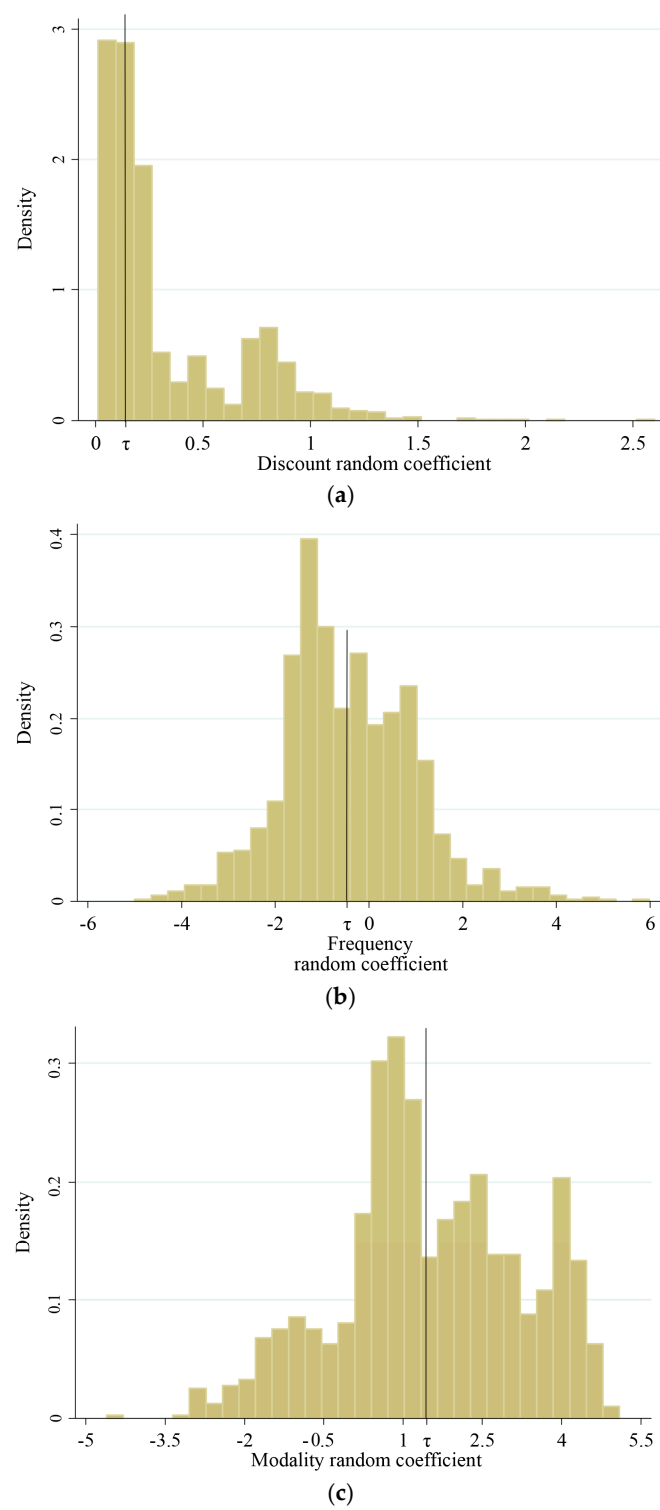
Results of the random parameters conditional logit show heterogeneity within parameters that may be discussed through the graphics in Figure 4. The graphics show the unconditional heterogeneity of the distribution of the four statistically significant parameters. Here, we discuss the heterogeneity of the parameter “Modality”, which we observed to be the most important among the attributes considered. The coefficient of this parameter has the value 1.447 (fourth column of Table 3), meaning that respondents preferred programmes that had the home collection service of the organic food waste. However, the graphic in Figure 4 concerning this parameter demonstrates that some of the respondents were willing to personally deliver the waste. The correlation matrix of random parameters (Table 5) shows that the parameter “Modality” is positively correlated with the one “Frequency” and negatively correlated with the one “Discount”. This means that interviewees willing to have the home collection service of the waste are often also the same who would participate with higher frequency and less attached to the discount.

Table 5. Correlation matrix of random parameters.

| | Frequency | Modality | Penalization | Discount |
|--------------|-----------|------------|--------------|----------|
| Frequency | 1 | | | |
| Modality | 0.086 *** | 1 | | |
| Penalization | −0.050 * | 0.028 | 1 | |
| Discount | 0.055 ** | −0.107 *** | 0.158 *** | 1 |

Note: * $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$.

A probit model was implemented in order to characterise respondents that are willing to deliver personally the organic food waste to retailers (positive coefficient for the parameter “Modality”). Results of the probit show that the probability of parameter “Modality” positively increases if respondents are male, old and less educated (Table 6). Furthermore, respondents that were not used to differentiating organic food waste show a higher probability of willingness to deliver it personally.

**Figure 4.** *Cont.*

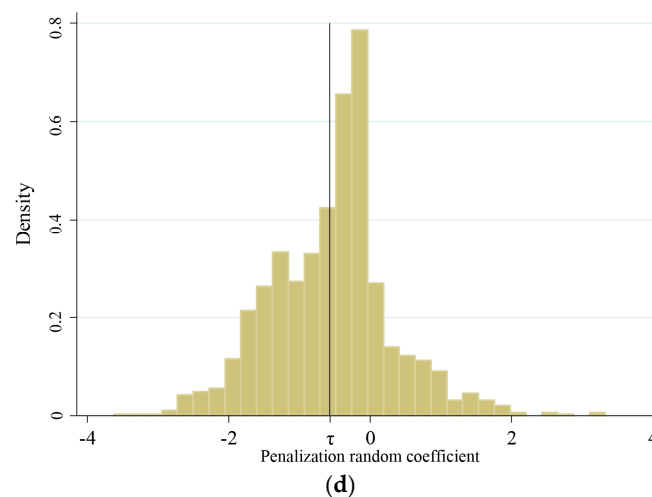


Figure 4. Distribution of random parameters. (a) Discount; (b) Frequency; (c) Modality; (d) Penalization.

Table 6. Probit model. Dependent variable positive coefficient for the parameter “Modality”.

| Variable | Coeff. | <i>p</i> -Value |
|---------------------|--------|-----------------|
| Economic classes | −0.022 | 0.601 |
| Organic waste | 0.276 | 0.030 |
| Gender (1 = female) | 0.292 | 0.011 |
| Age | −0.012 | 0.012 |
| Educational level | 0.150 | 0.013 |
| Household size | −0.032 | 0.396 |
| City size | −0.039 | 0.181 |
| South of Italy | 0.078 | 0.417 |
| _cons | 0.952 | 0.034 |

5. Discussion and Concluding Remarks

Circular economy attempts to design closed loops of resources in order to eliminate waste and reduce the impact of human activities on the environment. In this paper, we explored how consumers can be involved in closing loops when it comes to food waste. We designed a case study in order to investigate the role of novel technologies in consumers’ willingness to participate in circular economy strategies to reduce food waste. In our study, consumers’ participation was hypothesised as a programme to take back food waste to retailers. In so doing, we particularly aimed at eliciting knowledge concerning the attitude of consumers towards the idea of actively participate to this circularly designed loop.

For this purpose, we submitted a structured questionnaire to a representative sample of Italian households. A choice experiment in which consumers were asked to express their preferences about the attributes of a participation programme to the abovementioned circular loops was implemented. The sample was split in two groups in order to assess the potential influence of different technologies to the participation to the programme. A traditional technology (composting) and a radical innovative one (insects as feed), both suitable for recycling organic food waste in the framework of animal food productions, were presented.

A high proportion of respondents reacted positively to the scenario presented during the experiment. Most of them accepted both alternative programmes proposed in the five choice tasks of the questionnaire. The treatment concerning the technology used for the recycling of food waste had almost no effect on the choices of the interviewees. Respondents declared to be willing to participate to the circular loop according to similar percentages for both innovative solutions. This pattern let

us reject the hypothesis that acceptance of novel food technologies could have influenced consumers' attitude towards participation in circular loops. Even though repulsion for insects is highlighted as a determinant in the current scientific debate on acceptance and diffusion of insects as source of sustainable feed and food, when it comes to the circular economy, consumers' position seems to be more influenced by drivers related to the way participation is designed and organised.

The specific attributes of the take back programme had indeed clear effects in determining consumers' choices. Increasing the discount for purchasing animal products, as proposed by the programme, positively affected participation. This is consistent with the assumption that consumers want to be rewarded for the effort required in participating in a circular loop and a take back mechanism. Consequently, consumers also tended to prefer programmes in which they did not risk having a lower discount due to the delivery of non-organic waste. Consumers' attitudes towards penalisation led us to surmise that the proper collection of organic waste for recycling could be not an easy task. The responses to the choice tasks revealed also that consumers would prefer to limit the effort related to the participation. First, they reacted negatively to programmes in which they were more frequently required to deliver the organic food waste to retailers. Second, the analysis of trade-offs in monetary terms among contract attributes suggests that consumers would give away a big part of the discount in exchange for the collection at home of the organic food waste. Nevertheless, some of the respondents became more willingly committed to the mechanism proposed by the experiment irrespective of any rewards and efforts. These respondents stated their willingness to personally deliver the organic waste to retailers, having no problem in doing so twice a week, as well as to not being overly attached to the idea of compensation through discounts.

The outcomes of this study help to derive some concluding remarks regarding the peculiarity of using principles of circular economy to closed loops in the attempt to reduce waste at the post-consumption stage; that is consumers actively involved in the mechanisms of the circular economy. We assumed that consumers' position in the linear model of food supply chain is problematic. However, consistently with the recent literature on the possibility of changing consumer behaviour through socio-technological transformations (Mylan et al., 2016), our experiment shows that many consumers would be willing, if sufficiently rewarded, to be committed to participation in circular loops. Moreover, part of our sample shows the existence of a segment of the Italian population that is more willing to make personal efforts for the cause of a circular economy transition and that is less attached to monetary compensation as driver to participate. This result is aligned with recent efforts of policy makers concerning the development of a circular economy for contrasting waste production and reducing the extraction of natural resources. Moreover, it provides both incentives and insights for stakeholders willing to replicate into closed loops similar to the one described in this paper.

Our study has some limitations and some features of the supply chain described would deserve deeper investigation. First, the research was conducted by approaching to the circular economy with a perfectly hypothetical case, which could have affected respondents. Taking the cue from a real programme of participation would have enriched our experiment with more plausibility. We mitigated this problem by designing a "plot" as convincing as possible. However, this limitation is inherently linked to our purpose to depict a radically innovative case, which, at present, could not have been validated by reality. Second, choice of food waste for testing consumers' attitudes is a constraint for an immediate practical scalability of our model. The literature on food waste management is rich and we did not analyse the potential effectiveness and feasibility of our design. Nevertheless, the positive attitude showed by consumers for participation through the recycling of a perishable material like organic food waste make our conclusions worthy of being generalised to other materials recyclable through the circular economy.

Further research is needed in this field of inquiry. As regards the model used to treat our data, further studies should include the results of a Hierarchical Bayes model, in order to investigate possible benefits and drawbacks of this strategy in comparison to the use of the logit model. Our purpose was to give a contribution to the existing knowledge on how to consider a consumer dimension when

designing closed loops to reduce and eliminate food waste. Nevertheless, even though models of implemented circular economy are still rare, investigating drivers of consumers' choice when it comes to their actual commitment to participate in closed loops is still needed. Assessing the position of other potential stakeholders of the circular economy, like the retailers, is also necessary for addressing other challenges related to the implementation of new participation models.

Author Contributions: This paper is the result of teamwork. The Massimiliano Borrello, Luigi Cembalo and Stefano Pascucci conceived and designed the research. Francesco Caracciolo analyzed the data. Massimiliano Borrello, Alessia Lombardi and Luigi Cembalo discussed the results. Massimiliano Borrello and Luigi Cembalo wrote the paper. Stefano Pascucci supported in writing the paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. The Questionnaire

University of Naples Federico II, Italy

Dear Sir/Madam,

Today we invite you to participate in a survey carried out from the University of Naples Federico II about circular production methods in the agri-food sector. Circular production methods are grounded on the complete reuse of scraps and waste generated from production and distribution of products. In the case of agri-food products, these methods are based on the use of organic productions, biodegradable or compostable packaging, as well as on the use of solar and/or renewable energy. Moreover, all circular products are realised following ethic and responsibility production models.

The questionnaire is strictly anonymous. The information collected will be treated through an aggregate analysis and the results will be used only for scientific or educational objectives from the University of Naples Federico II. For this purpose, we would ask you to devote about 15 min of your time to fill in the questionnaire below. There are no right or wrong answers: what counts for us is your opinion.

Introductory Questions

- Are you the one who mainly manages the purchase of food in your family?
 - ☐ Yes
 - ☐ No
- Are you the one who mainly manages domestic food waste in your family?
 - ☐ Yes
 - ☐ No
- Does your family collect items for recycling?
 - ☐ Yes
 - ☐ No
- Does your family recycle organic waste?
 - ☐ Yes
 - ☐ No

Section 1—Experiment: Participation to a Project of Food Circular Economy

Current systems of food production and consumption generate an overexploitation of natural resources and huge food wastages. Some institutions and some researchers propose to replace the

current model with another one aimed both to reduce the consumption of resources and to eliminate the production of waste. This model implies the creation of networks in which the waste of some enterprises are used as production inputs from other enterprises (circular supply chains). Within the circular model, consumers can have an active role. Now you will be introduced to a method of circular supply chain that could be proposed to Italians in the future.

— Treatment with compost (Scenario 1)

During distribution and consumption of food products, huge amounts of food waste is generated. The University of Naples Federico II and an Italian big chain of supermarkets have created a method to eliminate organic waste through its reuse within the food chain. This method implies that domestic organic waste is reused through composting. This compost is used as organic matter within farms that produce feed for chickens, pigs and farmed fish. Compost improves soil fertility and can be used to replace chemical fertilizers in order to have positive effects on the environment. Consumers participate in this model by returning their organic waste to supermarkets. This waste, after being inspected, is added to the waste generated from supermarkets themselves. Consumers who participate are repaid through a discount on the purchase of animal products obtained by means of the circular method. These products are chicken, pork, fish and eggs that generated from this cooperation.

— Treatment with insects (Scenario 2)

During the distribution and consumption of food products, huge amounts of food waste is generated. The University of Naples Federico II and a big Italian chain of supermarkets have created a method to eliminate organic waste through the reuse within the food chain. This method implies that domestic organic waste is reused as feeding substrate for insects which, in turn, are used as feed for chickens, pigs and farmed fish. The use of insects as feed, other than being part of the natural behaviour of some animals, is a top source of nutrients. Insects have low environmental impact and a great potential in the feed sector. Consumers participate in this model by returning their organic waste to supermarkets. This waste, after being inspected, is added to the waste generated from supermarkets. Consumers who accept participation are repaid through a discount for the purchase of animal products obtained by means of the circular method. These products are chicken, pork, fish and eggs that were generated from this cooperation.

Please, assume that you will be asked to participate in a programme. This programme enables you to obtain discounts for the purchase of some selected food products in return for the restitution of an amount of organic waste. This amount can fluctuate from 1 up to 5 kg per week according to the number of members in your family. Discounts relate to the purchase of eggs, fresh pork or chicken, as well as fresh farmed fish like salmon, sea-bass and sea-bream.

Factors on which the invitation to participate in the project of circular economy are based—and on which we ask you to kindly focus your attention—are the following:

- Discount: consumers who participate in the programme receive a fixed monthly discount that can be spent as a coupon, for the purchase of the abovementioned products. The discount fluctuates according to both the frequency and the modality of the delivery of the organic waste, as well as to the duration of the participation.
- Frequency of Deliveries: there is a weekly commitment required from the participant to deliver the organic waste (once or twice a week).
- Modality of the Delivering: the modality of the delivery of the organic waste from the participant can be executed in two ways: 1. direct delivery to the supermarket; 2. collection at home by the supermarket.
- Duration of Participation: the duration in number of months of participation in the programme.
- Penalization for The Delivery of Non-Organic Waste: reduction, down to the annulment of the discount, if the organic waste delivered from the participant contains in part mixed or non-organic waste.

Now, we will show you a set of possible programmes in which you can participate that could regulate the relationship between the participant and the supermarket.

Programmes will be showed in pairs and will be indicated as proposal A and proposal B.

For each pair, please focus your attention on the conditions implied for each factors, and choose the proposal that you prefer.

Please, consider the following pair of proposals.

– Which programme do you prefer?

☐ Proposal A

☐ Proposal B

☐ Neither

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