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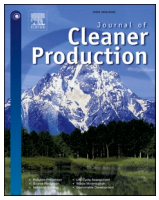

# What is the role of environmental sustainability knowledge in food choices? A case study on egg consumers in Italy

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ABSTRACT

This study aims at extending current evidence regarding the role of sustainability knowledge on food choices. In detail, the study focuses on Italian consumers' knowledge of the environmental impact of various stages of food production and consumption and explores whether and to what extent this affects preferences and willingness to pay (WTP) for food product attributes, with a focus on sustainability-related characteristics. This study applies a hypothetical Discrete Choice Experiment, using eggs as a case study, combined with a newly validated environmental impact knowledge scale. The results of this study contribute to the literature providing novel insights on the role of food-related sustainability knowledge as a driver of consumers' food choices; they can be valuable for proposing policies geared at reducing food-related environmental pressure.

## 1. Introduction

Ensuring sustainable food production and consumption is one of the seventeen Sustainable Development Goals (SDGs) set by the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015. The SDGs call for urgent actions by all countries - developed and developing – to maximize the socio-economic benefits of resource use while minimizing the climate, biodiversity, and pollution impacts (https://sdgs.un.org/goals). To ensure the achievement of such goals, the European Union has recently set specific actions for the food system within the Farm-to-Fork strategy, which aims, among others, at protecting biodiversity, providing healthy and nutritious food to consumers, and promoting sustainable food choices to alleviate diet-related environmental pressure. It is estimated that between 20 % and 30 % of the total human-caused environmental impact is related to food production and consumption (Tukker and Jansen, 2006). In such a context, consumers' day-to-day food consumption behaviors have a key role.

Over the past decade, interest in sustainability has increased and consumers started paying more attention to "green issues" (Special Eurobarometer, 2020). Although consumers' concern about sustainability and the environment is on the rise, their level of knowledge on these topics remains generally low (Peschel et al., 2016). This represents a problem of public relevance because lack of sustainability-related knowledge can lead consumers to underestimate the environmental consequences of daily consumption decisions, therefore impeding sustainable choices (Macdiarmid et al., 2016; Camilleri et al., 2019; Simeone and Scarpato, 2020; Hartmann et al., 2021).

In this context, the present study aims at extending evidence regarding the role of sustainability-related knowledge in affecting food purchasing decisions. In detail, the analysis explores whether and to what extent consumers' level of knowledge regarding sustainability issues affects preferences and willingness to pay (WTP) for sustainability-related food product attributes.

This paper uses a newly validated measure of environmental impact knowledge (EIK) that is specifically focused on the food domain (Hartmann et al., 2021). The EIK measure incorporates questions aimed at eliciting consumers' objective knowledge of the sustainability of both food supply and food consumption. To date, no other measures have incorporated both these aspects meanwhile allowing comparison across different food products (Hartmann et al., 2021). For this analysis, the EIK measure was combined with a hypothetical Discrete Choice Experiment (DCE) on eggs, distributed with an online survey to a sample of 996 Italian consumers.

Eggs were used as a case study for developing the DCE for multiple

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reasons. Firstly, the new Italian dietary guidelines, which consider both consumer health and the environmental impact of food consumption, recommend the reduction of processed and red meat in favor of poultry products, which have high nutritional value at a lower cost and lower environmental impact (Rossi et al., 2023). The consumption of poultry products, including eggs, will likely increase in the next years and a better understanding of consumer preferences is fundamental for both policy and market reasons.

Furthermore, at the global level, the egg industry is gradually shifting towards extensive production systems, able to improve animal welfare, reduce the environmental impact, as well as to protect biodiversity (Bonnefous et al., 2022; Caputo et al., 2023). However, to date, evidence regarding consumer preferences for sustainable egg attributes and their drivers is still mixed (Rondoni et al., 2020).

Additionally, very little is known about consumers' valuation of biodiversity protection. At least in the Italian market, only a few food products carry biodiversity-related attributes, and they are mainly in the wine segment.

The results of this study contribute to the literature in different ways. The findings provide novel insights into the link between consumers' objective knowledge of the environmental impact of food and food choices. The results extend available evidence on the use of the EIK construct as a measure of objective knowledge specifically focused on the food domain, and on its suitability to be used in consumer surveys. Moreover, the study sheds new light on consumers' preferences for sustainable egg attributes, including biodiversity protection. Consumer evaluation of such product characteristics is still unexplored. A better understanding of how consumers value biodiversity protection is key within the current food policy context, where biodiversity is a key target. Overall, these findings can guide the development of future policies and market strategies geared at increasing sustainable food consumption.

This paper is organized as follows. The next section provides a brief literature review regarding the main determinants of consumers' sustainable food choices. Section 3 provides the details on the data collection and the EIK scale, followed by the description of the DCE design and attribute explanation. Section 4 illustrates all the steps of the econometric analysis. The results are reported in section 5, which is followed by the discussion and the conclusion.

## 2. Literature background: consumers and sustainable choices

Several past studies have investigated the main barriers to sustainable consumption trying to understand the main reasons why people often struggle to make sustainable choices. Some studies showed that the higher prices of sustainable products can discourage consumers from buying environmentally friendly alternatives. For instance, Schimacher (2010) found that consumers' stated preferences for eco-labeled goods are higher among consumers with greater environmental consciousness and are lower among price-oriented consumers. Other studies indicated that price variations have a greater impact on sustainable choices compared to the effect of sustainability logos and labels (de Jonge et al., 2015; Hoek et al., 2017).

Other barriers to sustainable consumption are the perceived taste (because some consumers believe that products carrying sustainable characteristics are less tasty than conventional ones), and the lack of trust in sustainability-related claims (Vanhonacker et al., 2013; Waitt and Appleby, 2014; Campbell-Arvai, 2015; Bryła, 2016; Camilleri et al., 2019). Individual characteristics also affect preferences for sustainable products. For instance, some studies have linked individual personal values to their preferences for footprint-labeled foods (Grebitus et al., 2015).

Among all these factors, consumers' level of sustainability-related knowledge plays a key role when it comes to food choices. Past studies found that consumers are more likely to engage in environmentally conscious purchases when they know the meaning of product-level sustainability attributes or when their subjective environmental knowledge is high (Gifford and Nilsson, 2014; Peschel et al., 2016; Tong et al., 2020). On the contrary, they are unlikely to actively engage in sustainable behaviors if they do not have enough information about the problem, its possible consequences, and how their actions can contribute to solving it (Vermeier and Verbeke, 2006; Gifford and Nilsson, 2014; Shao et al., 2017; Camilleri et al., 2019; Hartmann et al., 2021). Even when consumers are motivated and concerned about sustainability, information and specific knowledge are required to properly choose sustainable alternatives among all those available (Lazzarini et al., 2017).

Previous studies highlighted that even though consumers' interest in sustainability has progressively increased over the last decades, their level of knowledge on these topics remains generally low (Peschel et al., 2016). Consumers have a limited understanding of the sustainable characteristics of products (Vermeier and Verbeke, 2006). Furthermore, consumers often have scarce knowledge about agricultural processes and a lack of information and awareness regarding the possible implications that their food purchasing decisions can exert on the food supply chain and, consequently, on the environment (Verbeke, 2005). Such lack of knowledge regarding the complexity of food production stages and their related impacts leads consumers to underestimate environmental consequences and therefore impedes sustainable choices (Camilleri et al., 2019; Simeone and Scarpato, 2020; Hartmann et al., 2021).

## 3. Methods

### 3.1. Data

The data were collected in Italy in January 2023 through a nationwide online survey distributed by a survey panel provider[1] to 1013 respondents. The online panel is well distributed in the national territory and the socio-demographic and economic characteristics are representative of the population census. Respondents were invited via email. They were informed that data were collected anonymously, that there were no predicted risks in participating in the study, and that they could opt-out at any time. Participants were considered eligible for the study only if they were older than 18 years old, not allergic to eggs, and bought eggs in the month before the survey. The final sample, after excluding incomplete questionnaires, resulted in 996 complete interviews.

The survey included a section with the EIK questionnaire (Hartmann et al., 2021), a section with the DCE on eggs, as well as a section aimed at eliciting the main sociodemographic and economic characteristics of the respondents. The order of presentation of the sections as well as the order of questions within each section were randomized across respondents to avoid ordering bias.

### 3.2. Environmental impact knowledge and survey questionnaire

A recently validated scale was used to elicit respondents' level of knowledge about the environmental impact of food (Hartmann et al., 2021). This construct has a peculiarity compared to previous measures: it considers the impact of both food production activities and food consumption choices using specific items to assess people' factual food-related environmental knowledge.

Most of the previous research used generic measures of sustainability knowledge, mainly based on subjective knowledge elicitation (i.e., how much individuals believe to know regarding environmental sustainability) (see for instance Peschel et al., 2016; Tong et al., 2020). Some studies suggested that subjective knowledge is a better predictor of environmentally friendly behaviors compared to objective knowledge (i.e., what consumers know) (Zhang et al., 2018; Peschel et al., 2016; Aertsens et al., 2011; Ellen, 1994). However, results are still mixed.

[1] More detailed information is available here: https://www.demetra.com/en/chi-siamo/.

Thøgersen et al. (2010) for instance, found that the adoption of sustainability labels was mainly related to objective knowledge. Furthermore, subjective measures suffer from several biases. They are strongly affected by psychological factors (Podsakoff et al., 2003; Jahedi and Méndez, 2014) and, in some cases, they are uncorrelated with objective measures of the variable of interest (Kaplan and Pathania, 2010; Jahedi and Méndez, 2014).

One of the main reasons why subjective knowledge is often preferred in consumer studies is that it is much easier to be elicited. On the contrary, a reliable assessment of consumers' objective knowledge is challenging (Liu et al., 2018).

The use of the recently developed EIK measure contributes to filling this gap providing a novel approach to explore the role of objective environmental knowledge in food choices. The construct consists of 16 items with varying difficulty levels, where respondents are asked to indicate the correct answers among the proposed multiple choices. The items are designed to focus on food items/groups that are typical of European countries and the questions touch on topics such as the seasonality of products, the environmental impact of production processes and transportation, etc. (full version of the EIK in the Supplementary Materials).

Individual responses are analyzed according to Hartmann et al. (2021): one point is assigned to correct answers, and 0 points to incorrect responses such that the maximum score achievable by each respondent was 16, corresponding to a high level of environmental impact knowledge (EIK).

Additionally, being interested in exploring whether and how individual level of environmental impact knowledge affects food choices with specific regard to sustainability-related product attributes. Respondents were further segmented into four sub-groups based on the achieved scores: EIK = 1 included respondents scoring lower than 5 (i.e., scarce EIK), EIK = 2 respondents with scores between 5 and 8 (corresponding to low-medium EIK), EIK = 3 with scores between 9 and 12 (medium-high EIK) and EIK = 4 respondents scoring higher than 12 (high EIK).

The survey questionnaire also included a section aimed at eliciting the socio-demographic and economic variables of the sample.

### 3.3. Choice experiment: attributes and procedure

The first step when designing a choice experiment is to choose the product of interest and select the attributes and levels to be used for experimentally designing the product alternatives. In this case, eggs were chosen as the product of interest, characterized by the following attributes: price for a 6-eggs box, yolk dimension, content of vitamin D, chicken rearing system, biodiversity protection, and the local production (Table 1).

The price levels were chosen to reflect current supermarket prices for eggs in Italy. Six levels allowed to cover a wide spectrum of price intervals, from entry prices to the highest prices of eggs with specific nutritional- and/or sustainability-related characteristics (e.g., nutrition claims, organic labels, etc.). The yolk dimension refers to the quality properties of eggs, which are generally valued for food preparation purposes, while the vitamin D content identifies eggs with enhanced nutritional profile. It is one of the most common nutritional-related attributes that can be found on eggs in the Italian market.

The rearing system, the biodiversity protection, and the local production were selected to refer to different dimensions of the product sustainability.

The rearing system refers to the animal welfare dimension, to which consumers have become increasingly interested over the past decade (Texeira et al., 2018; Lusk, 2019) such that the egg industry is gradually moving away from cage-based production systems in favor of free-range production methods, where animals have more space to move and live in better health conditions. (Lusk, 2019; Lusk, 2019). Past studies found that animal welfare can affect consumer preference for eggs more than environmental concerns (Heng et al., 2013) and that, in general, consumers are willing to pay more for free-range eggs compared to conventional products. The perceived nutritional and sensory quality of free-range eggs is also higher (Teixeira et al., 2018; Lusk, 2019).

Biodiversity protection is closely related to environmental sustainability. In the Italian market, this attribute is more commonly present in other food categories (especially wine) to signal products that promote and enhance sustainable agriculture, that respect the biodiversity of the territory as well as of the communities living on it (Mazzocchi et al., 2019). However, the importance attributed to biodiversity protection has remarkably increased over the past decade and is now a specific target also in international food policies. The maintenance of high biodiversity in the environment is considered an overriding goal for production activities, especially in the primary sector, and it is reasonable to expect that more and more food products will carry this attribute in the coming future. Therefore, it is crucial to understand how consumers evaluate it. Given that consumers might not be familiar with this attribute, a brief explanation was provided to all respondents before the DCE task (i.e., The attribute "Protects Biodiversity" identifies eggs produced from autochthonous chicken breeds, whose rearing contributes to biodiversity protection).

Finally, the attribute local production identified locally produced eggs. Local food can be described as food that has traveled a short distance or that is marketed directly by the producer[2] (Holloway et al.,

2007). Consumer interest in such product has increased worldwide in the last decade especially due to sustainability related reasons (Conner et al., 2010; Aprile et al., 2016; Zhang et al., 2018). According to previous studies, local food allows to reduce environmental impact thanks to the limited/absent carbon footprint associated with transportation. Furthermore, local production supports local economies and provides new market opportunities to farmers (Conner et al., 2010; Onozaka and McFadden, 2011; Aprile et al., 2016). However, especially in Europe, consumers tend to associate local foods also with tradition and with higher quality (Feldmann and Hamm, 2015; Aprile et al., 2016; Zhang et al., 2018). A brief explanation of the meaning of "Locally produced" was provided to all respondents before the CE to ensure correct understanding (i.e., The attribute "Locally produced" refers to eggs that are produced in the surrounding area of the selling point).

The allocation of attributes and attribute levels to the experimentally designed product alternatives was made using Ngene software version 1.3. An efficient design was developed resulting in 5 blocks, consisting of 6 choice tasks, each one composed of two purchase alternatives and an opt-out option (Fig. 1). The latter is commonly added to better mimic real purchasing situations, where consumers always can go away without buying any product. Compared to orthogonal designs, which aim to minimize the correlation in the data for estimation purposes,

**Table 1**
Attributes and levels for the Discrete Choice Experiment.

| Attribute | Levels |
|---|---|
| Price (€ for a 6-egg box) | 1.79, 2.09, 2.39, 2.69, 2.99 |
| Yolk | Big yolk/None |
| Vitamin D | Rich in vitamin D/None |
| Rearing system | Free-range/None |
| Biodiversity protection | Protects biodiversity/None |
| Local production | Local/None |

[2] There is no univocal definition of "local" food in terms of the geographical boundaries that should be used to define them. There is great variation in how consumers perceive local foods depending on the distance between the production site and the selling point. The literature shows that consumer perception of local food also varies across countries. For instance, in the US consumers perceive as local products that are sold within 100 miles from the production, while in European countries the distance is within 100 km (Aprile et al., 2016).

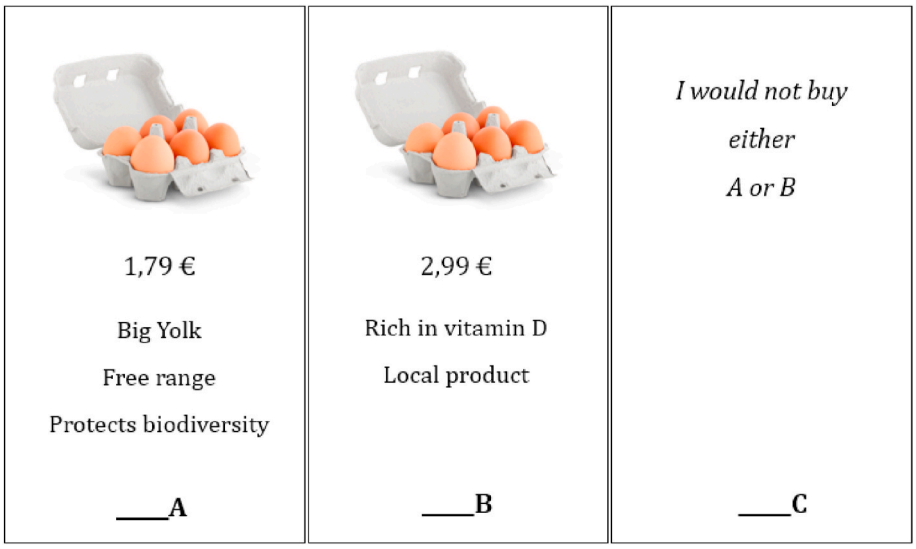


**Fig. 1.** Example of Choice task.

efficient designs yield data that enable estimation of parameters with as low as possible standard errors.

The so-called D-error represents the most commonly used measure of efficiency, and the goal of efficient designs is to minimize it. The lowest D-error achieved with our design was D-error = 0.07.

While hypothetical DCEs have become one of the most popular methods to elicit consumer preferences for products and product characteristics, the results obtained can suffer from hypothetical bias. This is due to the fact that, given the hypothetical nature of the survey, respondents may overstate their willingness to pay. To mitigate this bias, all respondents were provided with a Cheap Talk script before starting the DCE task (Appendix A). This method is based on the assumption that informing respondents about the risk of incurring hypothetical bias and reminding them about budget constraints can result in more reliable and less biased responses (Cummings and Taylor, 1999). This method has been largely tested in the literature and the results support its effectiveness (see for instance Carter et al., 2000; Silva et al., 2011; Glynn and Shupp, 2011; van Loo et al., 2011).

## 4. Econometric analysis

According to the random utility theory (McFadden, 1974), in DCEs individuals choose a specific product profile over others when the perceived utility of that profile exceeds the utility that could be derived from the other alternatives. The utility of consumer $n$ in choosing alternative $j$ in the choice situation $t$ can be expressed as:

$$U_{njt} = \beta'_n X_{njt} + \varepsilon_{njt} \quad (1)$$

where $x_{njt}$ is the vector of observable variables related to the individual $n$ choosing alternative $j$ in choice situation $t$; $\beta_n$ represents the vector of preference parameters related to the product attributes; and $\varepsilon_{njt}$ is the unobservable component of the utility function independent from $\beta$ and X, following a Type I Extreme Value distribution. Based on the assumption made about consumer preferences and their related distributions as well as on the composition of the unobserved portion of the utility function, several random utility model specifications can be used. Among these, Mixed Logit Model (MXL) specifications are commonly used to account for (i) heterogeneity in individual preferences and (ii) for the panel structure of the data given that each respondent answers six choice tasks (Train, 2003). However, previous studies showed that the presence of the opt-out alternative in the choice tasks, as in this case, can cause systematic effects related to the status-quo and to correlated random effects across the utilities of the two purchasing alternatives. The purchasing alternatives are always characterized by diverse combinations of attributes and levels, while the opt-out is constant throughout the CE. As shown in Scarpa and Alberini (2005) and Scarpa et al. (2007) this can be accounted for by adding an additional Error Component (EC) to the MXL. The resulting model (1), called MXL-EC, accounts for this additional source of variance, such that:

$$U_{njt} = \beta'_n X_{njt} + \eta_{nj} + \varepsilon_{njt} \quad (2)$$

where $\eta_{n_j}$ represents the individual specific EC, with zero mean, associated with the purchasing alternatives in each choice set, and not with the opt-out.

Applying the general equation in (2) to our specific choice context, the utility function can be specified as:

$$U_{njt} = \beta_0 * \text{opt-out}_{njt} + \beta_1 * \text{price}_{njt} + \beta_2 * \text{yolk}_{njt} + \beta_3 * \text{vitamin D}_{njt} + \beta_4 * \text{rearing system}_{njt} + \beta_5 * \text{biodiversity}_{njt} + \beta_6 * \text{local production}_{njt} + \eta_{n_j} + \varepsilon njt \quad (3)$$

In (3) $n = 1, \ldots, n$ represents the nth respondent, $t$ refers to the choice task, and $j$ to alternatives A, B, or C respectively, where C is the opt-out specified as a dummy-coded variable assuming value 1 when the opt-out is chosen and 0 otherwise. $\beta_0$ represents the alternative-specific constant associated with the opt-out alternative and $\beta_1$ is the parameter associated with the $\text{price}_{njt}$ attribute (continuous variable corresponding to the price for a 6-eggs box, which is treated as a fixed parameter[3]). The other parameters in the utility function ($\beta_2$, $\beta_3$, $\beta_4$, $\beta_5$, and $\beta_6$) represent the dummy-coded attribute level variables assuming value 1 when the attribute is present in the experimentally designed purchasing alternative and assumed to be random and following a normal distribution.

As a second step in the analysis, to investigate whether individual EIK has a role in affecting consumer preference intensity for sustainability-related attributes, the model in (3) was extended by including three interaction terms, as described in equation (4):

[3] The assumption of fixed price implies that respondents do not have heterogeneous preferences for this attribute. Although this might be untrue, fixing the price coefficient avoids identification problems occurring in models where all coefficients are random (Train, 2003). Additionally, this ensures that the estimated price coefficient is normally distributed and negative, consistently with the economic theory (meaning that consumers prefer lower prices ceteris paribus). Therefore, this approach has been commonly applied in numerous previous studies on consumer food choice behavior (Van Wezemael et al., 2014; De Marchi et al., 2016; De Marchi et al., 2019; Bazzani et al., 2017).

$$U_{njt} = \beta_0 * \text{opt-out}_{njt} + \beta_1 * \text{price}_{njt} + \beta_2 * \text{yolk}_{njt} + \beta_3 * \text{vitamin D}_{njt} + \beta_4 * \text{rearing method}_{njt} + \beta_5 * \text{biodiversity}_{njt} + \beta_6 * \text{local production}_{njt} + \beta_7 (\text{EIK} * \text{rearing system}) + \beta_8 (\text{EIK} * \text{biodiversity}) + \beta_9 (\text{EIK} * \text{production}) + \eta_{n_j} + \varepsilon njt \quad (4)$$

where EIK is the categorical variable assuming values from 1 to 4 depending on the individual level of environmental knowledge and $\beta_7$, $\beta_8$, and $\beta_9$ are the coefficients that capture the interaction between individual EIK respectively with the attributes rearing system, biodiversity, and local production. These interaction terms allow understanding whether different levels of EIK contribute to increase/decrease consumer preference for sustainability-related attributes. A positive sign of the interaction means that the higher the level of EIK, the higher the importance given to the specific attribute in the choice process.

After exploring the overall effect of individual EIK on sustainability-related attribute evaluation, a further investigation was focused on whether choice behavior varies across consumer segments characterized by different EIK scores. To this purpose, we estimated four additional models based on the utility function in (1): $\text{Model}_{\text{EIK1}}$ refers to the utility function of respondents with scarce EIK, $\text{Model}_{\text{EIK2}}$ estimates preference for respondents with low-medium EIK, $\text{Model}_{\text{EIK3}}$ for respondents with medium-high EIK and, finally, $\text{Model}_{\text{EIK4}}$ for respondents with high EIK scores.

Then, the marginal WTP of respondents in the four EIK sub-groups was calculated for each product attribute. Marginal WTP was calculated as the negative ratio of the partial derivative of the utility function to concerning the attribute of interest, divided by the derivative of the utility function with respect to the price. It is equal to the negative ratio of the estimated parameter of the non-price *k* attribute and the price parameter ($-\beta_k/\beta_1$). The Wald test was used to ensure that the estimated WTPs were statistically different from zero.

**Table 2**
Socio-demographic and economic characteristics of the full sample and across environmental impact knowledge groups.

| Socio-demographic and economic characteristics | | *% of total* | | | | |
|---|---|---|---|---|---|---|
| | | Full sample | EIK_1 | EIK_2 | EIK_3 | EIK_4 |
| | | *(N=996)* | *(N=129)* | *(N=313)* | *(N=417)* | *(N=137)* |
| *Age* | 18–24 years | 4.4 | 3.9 | 3.2 | 5.3 | 5.1 |
| | 25–34 years | 16.6 | 17 | 19.5 | 13.7 | 18.2 |
| | 35–44 years | 20.4 | 22.5 | 20.8 | 19.7 | 19.7 |
| | 45–54 years | 22.6 | 25.6 | 25.2 | 20.1 | 21.2 |
| | 55–64 years | 20.2 | 18.6 | 18.2 | 22.0 | 20.4 |
| | >65 years | 15.9 | 12.4 | 13.1 | 19.2 | 15.3 |
| *Gender* | Male | 49.6 | 40.3 | 45.7 | 51.6 | 61.3 |
| | Female | 50.1 | 59.7 | 54.0 | 48.0 | 38.7 |
| | Non-binary | 0.2 | – | 0.3 | 0.2 | – |
| | I do not want to answer | 0.1 | – | – | 0.2 | – |
| *Monthly Net Income* | < 1000 € | 19.6 | 31.8 | 23.0 | 16.3 | 10.2 |
| | 1.000–2000 € | 53.3 | 49.6 | 55.3 | 51.6 | 57.7 |
| | 2.000–4.000 € | 23.5 | 14.0 | 20.4 | 27.3 | 27.7 |
| | 4.000–6000 € | 3.0 | 1.5 | 1.0 | 4.6 | 4.4 |
| | > 6.000 € | 0.6 | 3.1 | 0.3 | 0.2 | – |
| *Self-perceived economic condition* | Much worsened | 3.3 | 4.6 | 2.6 | 3.6 | 2.9 |
| | Worsened | 31.22 | 31.0 | 33.9 | 29.98 | 29.2 |
| | Unchanged | 55.62 | 52.7 | 55.9 | 55.64 | 57.7 |
| | Improved | 8.94 | 10.9 | 6.7 | 10.55 | 7.3 |
| | Much improved | 0.90 | 0.8 | 1.0 | 0.24 | 2.9 |
| *Education* | Elementary School | 0.70 | 2.3 | 1.0 | 0.24 | |
| | Mid School | 8.94 | 14.7 | 9.3 | 7.91 | 5.8 |
| | High School | 52.91 | 52.7 | 54.6 | 53.96 | 46.0 |
| | College Degree | 11.45 | 10.8 | 12.1 | 11.27 | 10.9 |
| | Master's degree | 23.49 | 17.8 | 20.8 | 24.46 | 32.1 |
| | Higher education | 2.51 | 1.5 | 2.2 | 2.16 | 5.1 |
| *Household size* | 1 component | 10.84 | 12.4 | 10.2 | 9.35 | 15.3 |
| | 2 components | 28.92 | 27.1 | 27.8 | 31.89 | 24.0 |
| | 3 components | 29.82 | 30.2 | 28.7 | 30.46 | 29.9 |
| | 4 components | 23.59 | 27.1 | 25.2 | 20.62 | 25.5 |
| | 5 or >5 components | 6.83 | 3.1 | 8.0 | 7.67 | 5.1 |
| *Children younger than 5 years old* | No | 89.2 | 87.6 | 87.2 | 90.9 | 89.8 |
| | At least 1 | 10.8 | 12.4 | 12.8 | 9.1 | 10.2 |
| *Vegetarian/vegan diet* | No | 97.3 | 100 | 98.4 | 97.1 | 92.7 |
| | Yes | 2.7 | 0 | 1.6 | 2.9 | 7.3 |
| *Geographic area* | Northern Italy | 45.7 | 42.6 | 43.1 | 45.8 | 54.0 |
| | Central Italy | 20.8 | 21.7 | 20.1 | 20.9 | 21.2 |
| | Southern Italy | 33.5 | 35.7 | 36.7 | 33.3 | 24.8 |

## 5. Results

### 5.1. Sample charactristics

Table 2 illustrates the socio-demographic and economic characteristics of the respondent sample (N = 996). Gender is well-balanced, age, education, and income overall reflect the distribution of the Italian population.[4] Little less than 50 % of the respondents are from northern Italy, which is the most densely populated area, while about 21 % are from central Italy and the remaining 33 % are from Southern regions.

Interesting differences emerge when analyzing the socio-demographic and economic variables across respondents with different EIK levels. Looking at the distribution of gender it is possible to notice that in groups EIK_1 and EIK_2 females prevail, while the reverse happens in groups EIK_3 and EIK_4 where the percentage of males reaches 61 % suggesting that men have an overall higher environmental knowledge compared to women. Differences can be observed also when looking at the average education level: the percentage of respondents with a master's degree or higher education levels is higher among respondents with medium-high and high EIK.

Furthermore, across EIK groups 1 and 2 the percentage of respondents from northern, central, and southern regions is roughly the same (respectively about 42 %, 21 %, and 36 %), while changes can be observed in groups 3 and 4. In the latter groups, the number of people from northern regions is notably higher, especially in the group with the highest EIK (almost 55 % is from the North of the country). This is likely due to the higher average education level of the population in northern Italy. Another key difference regards respondents' dietary habits: in group EIK_1 there are no respondents following a vegetarian/vegan diet, in group EIK_2 less than 2 %, while the percentage increases progressively with the increase in EIK until reaching 7 % among individuals with high environmental knowledge. This is a clear sign of the higher environmental concern of individuals with high EIK, which likely favors diet-related environmentally friendly behaviors.

### 5.2. Food choice behavior

Table 3 illustrates the results of the model estimates for the full sample: from the left side, the table reports the results of the MXL, the MXL-EC (Model A), and the MXL-EC (Model B) with interactions between the EIK categorical variable and the sustainability-related product attributes. All models are estimated based on 5976 choices collected from 996 respondents. The MXL-EC specification is chosen for presenting results given the better model fit and the significant EC, which corroborate the appropriateness of this specification in explaining choice behavior for the experimentally designed eggs.

The results of Model A show that the price coefficient is negative and significant at the 1 % level, indicating that consumers overall prefer products with lower prices. The opt-out also displays a negative sign and is significant at a 1 % level, meaning that respondents obtain higher utility from buying one of the two product alternatives instead of choosing not to buy anything. As for the other product attributes, all coefficients are significant at a 1 % level demonstrating that all the selected characteristics are relevant for respondents when choosing the preferred product.

In detail, compared to baseline eggs, respondents prefer free-range and locally produced alternatives, whose production helps protect environmental biodiversity, rich in vitamin D, and with bigger yolk. This is consistent with previous literature on consumers' egg preferences, showing that both sustainability-related attributes and quality properties are important when consumers evaluate different egg alternatives (Ahmad Hanis et al., 2013; Ayim-Akonor and Akonor, 2014; Gracia et al., 2014; Rahmani et al., 2019). However, as shown by the coefficients' magnitude, respondents give more value to the sustainability-related attributes (free-range, local production, and biodiversity protection in order of importance) compared to the presence of vitamin D and the yolk dimension, which is the least important attribute ceteris paribus. Furthermore, the high statistical significance of the standard deviations of all the main effects shows heterogeneity in respondents' preferences for all egg attributes.

These results are overall in line with those of Model B including the interactions of EIK respectively with the rearing system, the biodiversity protection, and the local production attributes. The mean parameter estimates of the attributes reveal the same choice pattern that emerged in Model A, with one exception. In fact, in this model, the biodiversity protection coefficient loses its significance. Highly significant is the interaction of the biodiversity attribute with the EIK, which indicates that the utility that respondents obtain from choosing products that protect biodiversity increases with the increase in their level of environmental knowledge. Overall, this suggests that preferences for biodiversity protection are better explained if they are interacted with the EIK level.

The interaction of EIK with local production is also positive and significant, meaning that higher levels of EIK increase the importance attached to this product attribute. However, the significance of the interaction local*EIK is weaker compared to the biodiversity protection*EIK (i.e., 10 % level). This may be because consumers sometimes associate local food products not only with increased environmental sustainability but also with increased quality due to perceived higher nutrition quality and/or taste (Born and Purcell, 2006). Finally, the interaction Rearing system*EIK is not significant. The free-range attribute relates to animal welfare, which is a specific dimension of sustainability that is less directly linked with the environment.

To further explore the role of EIK in affecting food choice behavior and respondents' evaluation of Table 4 reports the results of the MXL-EC models respectively estimated for each of the four EIK subgroups: from low EIK on the left side, to high EIK on the right. As expected, the price is negative and significant at a 1 % level in all subgroups as well as the opt-out coefficient. In group EIK_1 the most important attribute after the price, is the free-range system, followed by the local production, both positive and significant at a 1 % level. The biodiversity protection as well as the yolk dimension and the presence of vitamin D are not relevant to the product choice. When moving to group EIK_2, including respondents with low-medium levels of environmental impact knowledge, it is possible to observe that, after price, the free-range system has the highest mean effect, immediately followed by the local production having a slightly lower coefficient. The third non-price attribute in order of importance is the presence of vitamin D, followed by biodiversity protection with roughly the same coefficient magnitude and the same significance (both at 1 % level). In group EIK_3, the most important attribute is the free range, followed by local, biodiversity protection, vitamin D, and the yolk dimension having the same mean effect. All non-price attributes are positive and significant at a 1 % level. The choice pattern of respondents with the highest EIK level is similar to the one observed in group EIK_3. However, in this group, the bigger yolk dimension does not increase consumer utility and the significance of the vitamin D coefficient is at a 5 % level.

### 5.3. Willingness to pay

Willingness to pay for product attributes across EIK groups is illustrated in Table 5. In general, respondents show higher WTP values for sustainability-related attributes, compared to both the presence of vitamin D and the yolk dimension. The highest WTP values relate to free-range and locally produced eggs, in all groups. However, in group EIK_1 the estimated values are respectively 0.47 € and 0.45 € for a 6-egg box,

[4] Detailed information on the main socio-demographic and economic characteristics of the Italian population are provided by the Italian institute of statistics (ISTAT and are freely available at: https://demo.istat.it/tavole/?t=indicatori&l=it).

**Table 3**
MXL and MXL-EC estimation results.

| Attribute | | MXL | | Model A | | Model B | |
|---|---|---|---|---|---|---|---|
| | | | | MXL-EC | | MXL-EC + Interactions | |
| Yolk | Mean | 0.203 | *** | 0.173 | *** | 0.173 | *** |
| | | *(0.067)*[1] | | *(0.056)*[1] | | | |
| | St. Dev. | 1.190 | *** | 0.799 | *** | 0.806 | *** |
| | | *(0.097)* | | *(0.088)* | | *(0.088)* | |
| Vitamin D | Mean | 0.381 | *** | 0.312 | *** | 0.312 | *** |
| | | *(0.066)* | | *(0.059)* | | *(0.059)* | |
| | St. Dev. | 1.304 | *** | 0.963 | *** | 0.960 | *** |
| | | *(0.093)* | | *(0.083)* | | *(0.082)* | |
| Rearing system | Mean | 1.316 | *** | 1.091 | *** | 0.861 | *** |
| | | *(0.085)* | | *(0.068)* | | *(0.172)* | |
| | St. Dev. | 1.455 | *** | 1.073 | *** | 1.070 | *** |
| | | *(0.097)* | | *(0.088)* | | *(0.088)* | |
| Biodiversity protection | Mean | 0.502 | *** | 0.396 | *** | −0.079 | |
| | | *(0.074)* | | *(0.065)* | | *(0.173)* | |
| | St. Dev. | 1.243 | *** | 0.963 | *** | 0.952 | *** |
| | | *(0.094)* | | *(0.086)* | | *(0.086)* | |
| Local production | Mean | 1.202 | *** | 1.004 | *** | 0.753 | *** |
| | | *(0.073)* | | *(0.061)* | | *(0.140)* | |
| | St. Dev. | 1.136 | *** | 0.802 | *** | 0.793 | *** |
| | | *(0.086)* | | *(0.079)* | | *(0.081)* | |
| Rearing system*EIK | Mean | | | | | 0.092 | |
| | | | | | | *(0.062)* | |
| Biodiversity protection*EIK | Mean | | | | | 0.190 | *** |
| | | | | | | *(0.061)* | |
| Local production*EIK | Mean | | | | | 0.100 | * |
| | | | | | | *(0.051)* | |
| Price | Mean | −1.934 | *** | −1.608 | *** | −1.609 | *** |
| | | *(0.091)* | | *(0.061)* | | *(0.060)* | |
| Opt-out | Mean | −5.208 | *** | −6.288 | *** | −6.300 | *** |
| | | *(0.211)* | | *(0.326)* | | *(0.328)* | |
| Error Component | Mean | | | 2.452 | *** | 2.461 | *** |
| | | | | *(0.293)* | | *(0.294)* | |
| ***Model fit*** | | | | | | | |
| Log-Likelihood | | −4078.08 | | −3997.46 | | −3990.45 | |
| AIC[a] | | 8180.2 | | 8020.9 | | 8012.9 | |
| Number of choices | | 5976 | | 5976 | | 5976 | |

Note: ***significant at 1 %, **significant at 5 %, and *significant at 10 %.
[1]Standard errors in parenthesis.
[a] AIC: Akaike information criterion.

marginal WTP for such attributes increases with the increase in consumers' level of environmental knowledge. WTP for local eggs ranges between 0.64 and 0.66 € across groups EIK 2, 3, and 4, while WTP for free-range eggs are more heterogeneous. Respondents with low-medium EIK would pay 0.67 € compared to EIK_1, namely 0.20 € more. When moving to EIK_3 and 4 WTP estimates for free-range eggs further increase and exceed 0.70 € (~0.30 € more compared to group EIK_2). As for biodiversity protection, WTP values across respondents with scarce EIK are not statistically different from zero, while they increase notably across respondents with low-medium and higher EIK: ~0.22 € both in EIK_2 and 3, and 0.57 € across respondents in EIK_4.

## 6. Discussion

The results of this study provide several insights into consumer preferences for eggs and on the role of food-related environmental impact knowledge in food choice behaviors.

First of all, the results highlight that sustainability-related attributes are important for consumers when choosing different egg products, which is in line with the results of previous studies (Andersen, 2011). Overall, the three sustainability-related attributes considered in this study (i.e., rearing system, biodiversity protection, and local production) provide higher utility to consumers compared to the other quality attributes of the product. In this context, the recent tendency observed in the egg industry to shift towards extensive production systems seems in line with consumer needs.

Indeed, the average willingness to pay elicited for sustainability-related characteristics is higher compared to the other product attributes (Tully and Winer, 2014).

One of the main results of this study, however, regards the role of consumers' food-related environmental impact knowledge in affecting food choices. The findings show that people with different levels of EIK also have different food preferences. In general, the higher the level of EIK, the higher the importance given to the three sustainability-related attributes considered in this study, although differences are observed across groups.

In particular, the DCE included two sustainability-related attributes that are familiar to consumers (i.e., rearing system and local production), as they are widespread in the Italian market on various food products, including eggs. The third attribute (i.e., biodiversity protection) is instead less likely to appear on food labels and is almost exclusively displayed on wines. Therefore, consumers are less familiar with it. Interestingly enough, the latter attribute is the one that is mostly affected by EIK, which considerably increases consumers' willingness to pay. The analysis conducted in this research does not allow us to derive robust conclusions on the reasons behind the strong relationship between consumers' valuation of the biodiversity attribute and environmental knowledge. However, it is plausible that consumers with high environmental knowledge are more interested and more informed about sustainability in general, including the concept of biodiversity and its value. Moreover, it is also reasonable that specific knowledge of the environmental impact of food enables consumers to better evaluate and trade-off the environmentally friendly attributes, even when they do not specifically know their meaning or when they have not been previously

**Table 4**
MXL-EC by EIK subgroups.

| Attribute | | $Model_{EIK\_1}$ (N = 129) | | $Model_{EIK\_2}$ (N = 313) | | $Model_{EIK\_3}$ (N = 417) | | $Model_{EIK\_4}$ (N = 137) | |
|---|---|---|---|---|---|---|---|---|---|
| Yolk | Mean | 0.047 | | 0.068 | | 0.262 | *** | 0.283 | |
| | | *(0.171)*[1] | *(0.095)*[1] | | *(0.090)*[1] | | *(0.200)*[1] | | |
| | St. Dev. | 1.096 | *** | 0.702 | *** | 0.748 | *** | 1.023 | *** |
| | | *(0.212)* | | *(0.152)* | | *(0.158)* | | *(0.281)* | |
| Vitamin D | Mean | 0.231 | | 0.361 | *** | 0.276 | *** | 0.416 | ** |
| | | *(0.162)* | | *(0.099)* | | *(0.101)* | | *(0.176)* | |
| | St. Dev. | 0.860 | *** | 0.834 | *** | 1.174 | *** | 0.883 | *** |
| | | *(0.218)* | | *(0.133)* | | *(0.141)* | | *(0.267)* | |
| Rearing system | Mean | 0.830 | *** | 0.974 | *** | 1.276 | *** | 1.286 | *** |
| | | *(0.173)* | | *(0.113)* | | *(0.117)* | | *(0.248)* | |
| | St. Dev. | 1.058 | *** | 0.970 | *** | 1.139 | *** | 1.400 | *** |
| | | *(0.213)* | | *(0.152)* | | *(0.141)* | | *(0.327)* | |
| Biodiversity protection | Mean | 0.261 | | 0.342 | *** | 0.374 | *** | 1.010 | *** |
| | | *(0.168)* | | *(0.102)* | | *(0.107)* | | *(0.225)* | |
| | St. Dev. | 0.453 | | 0.759 | *** | 1.099 | *** | 1.255 | *** |
| | | *(0.315)* | | *(0.152)* | | *(0.144)* | | *(0.276)* | |
| Local production | Mean | 0.800 | *** | 0.929 | *** | 1.132 | *** | 1.146 | *** |
| | | *(0.157)* | | *(0.098)* | | *(0.107)* | | *(0.215)* | |
| | St. Dev. | 0.625 | *** | 0.740 | *** | 0.809 | *** | 1.237 | *** |
| | | *(0.178)* | | *(0.144)* | | *(0.142)* | | *(0.286)* | |
| Price | Mean | −1.762 | *** | −1.434 | *** | −1.704 | *** | −1.775 | *** |
| | | *(0.179)* | | *(0.094)* | | *(0.104)* | | *(0.197)* | |
| Opt-out | Mean | −6.356 | *** | −5.870 | *** | −6.654 | *** | −7.422 | *** |
| | | *(0.746)* | | *(0.500)* | | *(0.511)* | | *(1.444)* | |
| Error Component | Mean | 2.447 | *** | 2.418 | *** | 2.604 | *** | 2.925 | ** |
| | | *(0.596i)* | | *(0.410)* | | *(0.386)* | | *(1.336)* | |
| ***Model fit*** | | | | | | | | | |
| LL | | −555.61 | | −1296.08 | | −1609.52 | | −504.67 | |
| AIC[a] | | 1137.2 | | 2618.2 | | 3245.0 | | 1035.4 | |
| Number of choices | | 774 | | 1878 | | 2502 | | 822 | |

Note: ***significant at 1 %, **significant at 5 %, and *significant at 10 %.
[1]Standard errors in parenthesis.
[a] AIC: Akaike information criterion.

**Table 5**
Mean WTP across EIK subgroups.

| | WTP €/6-egg box | | | | |
|---|---|---|---|---|---|
| | Full sample | EIK_1 | EIK_2 | EIK_3 | EIK_4 |
| Yolk | 0.11*** | – | – | 0.15*** | – |
| Vitamin D | 0.19*** | – | 0.25*** | 0.16*** | 0.23*** |
| Rearing system | 0.68*** | 0.47*** | 0.68*** | 0.75*** | 0.73*** |
| Biodiversity protection | 0.25*** | – | 0.24*** | 0.22*** | 0.57*** |
| Local production | 0.62*** | 0.45*** | 0.65*** | 0.66*** | 0.65*** |

Note: ***significant at 1 %, **significant at 5 %, and *significant at 10 %.

exposed to them.

From a methodological standpoint, this study supports the use of the EIK developed by Hartmann et al. (2021) as a measure of objective knowledge in food choice contexts. However, the reliability of the scale in experimental contexts should be further explored especially in non-European contexts. This would allow assessing the robustness and adaptability of the construct to different dietary patterns.

The analysis has some caveats that need to be discussed. Firstly, the findings may be product-dependent and may vary when considering different foods. Therefore, further studies should consider comparisons across different food products to assess the robustness of the results. Moreover, as in all hypothetical DCEs the product images as well as the choice and allocation of the attributes are specifically designed according to the aims of the research. Hence, the experimental design may increase/decrease the salience of certain product characteristics somewhat affecting stated preferences. Another limitation is related to the hypothetical nature of the DCE, and the consequent risk of hypothetical bias. Despite the cheap talk script adopted in this study has been demonstrated to be a reliable method to mitigate such bias, there is still the possibility that WTP estimates do not truly represent the reality. Future studies should aim at filling these gaps to provide more robust results regarding the role of environmental knowledge in food choices and the reliability of the EIK.

## 7. Conclusion

The results support previous evidence showing that consumers have become increasingly interested in sustainability issues and that, compared to the past, they seem to pay more attention to environmentally friendly characteristics when buying food (Shao et al., 2017; Camilleri et al., 2019; Hartmann et al., 2021). This is important because consumers' choice of sustainable products can have a positive effect on firms' performances regarding the cost of sold goods and the net income (Tully and Winer, 2014; Carter et al., 2000). In other words, the demand-pull could stimulate the supply to provide more and more sustainable product alternatives to consumers in the future.

The results also stress the importance of accounting for consumers' environmental knowledge when analyzing consumers' choice behavior for food with sustainable characteristics. Environmental knowledge seems a key driver of consumer preferences for sustainability-related attributes and contributes to explaining preference heterogeneity. The level of consumer environmental knowledge should be carefully considered when developing strategies aimed at increasing sustainable food consumption. Indeed, policy measures addressed to increase sustainability of food choices are less effective when consumers do not have enough knowledge to understand them (Hartmann et al., 2021). In light of the recent EU food policies geared at promoting sustainable food production and consumption, it is expected that a growing number of labels signaling various aspects related to sustainability will enter the market. Therefore, consumers' capability to understand their meaning will be crucial.

## CRediT authorship contribution statement

**Elisa De Marchi:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Giulio Scappaticci:** Conceptualization. **Alessandro Banterle:** Writing – original draft, Supervision, Conceptualization. **Cristina Alamprese:** Writing – original draft, Supervision, Project administration, Funding acquisition, Conceptualization.

## Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly in order to check English grammar. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2024.141038.

## Appendix A. Cheap Talk Script

The results of previous similar studies indicate that in some cases people give a certain answer, although they behave differently in their day-to-day life. One possible reason is that being in a hypothetical context, as in this survey, might lead people to understate the importance of their choices because these do not have a concrete effect on their real lives. In fact, individuals need to face their budget constraints only when they are in a real purchasing situation and must pay for the products that they choose to buy.

We ask you to keep this in mind while answering to next questions and to provide real responses. Please, behave as if you were in a real grocery store to buy food for yourself or your family.

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