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Scientific information and cognitive bias in the case of New Breeding Techniques: exploring Millennials behaviour in Italy

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Abstract. The paper explores consumers' acceptance of New Breeding Techniques (NBTs) in the agri-food sector. Our main research question concerns the role of information in shaping consumers' attitude towards genetically modified food and new breeding techniques in agricultural production. To this extent, we use a Multinomial Logit Model to analyse changes or confirmations of prior opinions on food safety concerns and environmental risks associated with modern biotechnologies once scientific information has been provided. Our findings confirm the Bayesian hypothesis according to which people combine their prior belief with new information to converge scientific information in the case of food safety. We also found a higher probability of confirmation bias, with people less willing to change their prior beliefs, when environmental risks are concerned.

Keywords: genome editing, millennials, food safety, environmental risks, biotechnology, Multinomial Logistic Regression.
JEL codes: B4, Q5, Q00.

HIGHLIGHTS:

- Providing people with information on NBTs is important to allow people to make an unbiased judgment on them.
- Convergence towards new information received is lower when concerns are about environmental risks connected to NBTs and higher in the case of food safety concerns.
- Convergence to scientific information is lower for people with a higher level of knowledge on biotechnologies.
- Communication on new breeding techniques should carefully address people's concerns on potential environmental impacts to avoid consumer rejection of NMTs.

INTRODUCTION

New Breeding Techniques (NBTs) based on genome editing (GE) have progressed rapidly in recent years, succeeding in creating plants with novel traits. These techniques are summarized as New Plant Breeding Techniques (Lusser *et al.*, 2012).

Different from "first generation" GMOs, which include foreign genetic material from different organisms, NBTs, such as CRISPR/Cas or cisgenesis among others, involve the selective alteration of DNA at certain parts of the genome obtained by several methods such as point mutations, the excision or incorporation of new sequences. Possible applications of NBTs in agriculture include the development of new varieties resistant to abiotic or biotic stress i.e., climate change, drought, pests, or other diseases (Mishra, Zhao, 2018). In this respect, NBTs could facilitate sustainable agro-ecological intensification (Ryffel, 2017). Furthermore, NBTs are also developed to create new products as functional food or food with other desired attributes.

The debate on NBTs regulation has gained further attention since the Court of Justice of the European Union concluded, in 2018, that, according to the EU's regulatory framework for genetically modified organisms (GMOs), targeted, genome-editing mutagenic technologies are GMOs, regardless of whether any foreign DNA is present in the final variety (Purnhagen, Wesseler, 2020). Already, in 2013, the European Academies Science Advisory Council (EASAC) concluded that «the trait and product, not the technology, in agriculture should be regulated, and the regulatory framework should be evidence-based» (EASAC 2013). This statement was the result of a very comprehensive analysis – based on solid science published in the previous 20 years – on the risks and benefits of crop NBTs, which did not find evidence for an intrinsically higher risk of genetic engineering in comparison to conventional breeding technologies such as mutagenesis. Since then, many scientists and other stakeholders have been calling for liberalisation of NBTs claiming that it is not possible to distinguish new varieties from those obtained by other more consolidated genetic methods such as mutagenesis or from mutations that happened in nature (Broll *et al.*, 2019; Callaway, 2018; Dederer *et al.*, 2019; Zimny, Sowa, 2021). According to Halford (2019) and many other scholars, there is an urgent need for the European Union to shift its position on plant biotechnology if agriculture is to meet the challenges of coming decades.

In 2021, the European Commission published a new study, on request by the Council of the EU, concluding that while NBTs could contribute to more sustainable food systems, current EU GMO regulations pose challenges to the development of innovative genetic technologies. According to this report, views from MS and stakeholders were diversified. In Europe, for example, biotechnologies are sometimes considered as potentially harmful to both humans and nature (Marangon *et al.*, 2022; Lucht, 2015; Malyska *et al.*, 2106), even if the general opinion is characterized by limited, and often negatively biased knowledge. Individuals' risk perception is the subjective judgement that might diverge from the technical risk estimate provided by experts (Slovic, 1987; Van Kleef *et al.*, 2007) on the basis of psychological, attitudinal, and cultural factors (Verbeke *et al.*, 2007). Moreover, some advocacy groups such as Greenpeace[1], emphasizing several concerns such as side effects and off-target effects, as well as the possibility of negative socio-economic impacts, make a claim for a restrictive regulatory approach or underline questions of corporate power surrounding plant genome editing (Helliwell *et al.*, 2019).

With this study we aim to contribute to the literature providing additional evidence regarding a) the opinion of Italian university students on NBTs; b) understanding to what extent, if present, consumers' attitude towards NBTs concerns mainly food safety or environmental risks; c) the role of new information in modifying people's attitude towards genetically modified food.

1. THEORETICAL FRAMEWORK, OBJECTIVES OF THE STUDY AND RESEARCH QUESTIONS

In the light of this debate, researchers have paid increased attention to consumers' attitudes towards GM food and the NBTs and to the role of information. According to several studies, consumer knowledge of genetic techniques is generally low (McFadden, Lusk, 2016; Colson, Rosou, 2013; Hwang, Nam, 2021). A study by McGarry *et al.* (2012) compares the knowledge of consumers in the United States, Japan, and Italy, showing that US consumers are more likely to be at least somewhat familiar with GMOs (40.9% reported being somewhat or very familiar) compared with Italian (28.0%) and Japanese consumers (33.3%). Others have highlighted consumer aversion expressed in preferences for production bans or mandatory labels (Carlsson *et al.*, 2007; Costanigro, Lusk, 2014). Several approaches have been utilized such as estimating the willingness-to-pay to avoid GM food (Frewer *et al.*, 2013; Hess *et al.*, 2016), theoretical models related to perceived risks and benefits (Bredahl, 2001; Frewer *et al.*, 2016), responses to information (Huffman *et al.*, 2007; Lusk *et al.*, 2004), and psychological factors (Lusk *et al.*, 2014).

Beghin and Gustafson (2022) conducted an extensive survey of existing studies on consumers' attitude

[1] https://www.greenpeace.org/eu-unit/issues/nature-food/45559/new-gmos-danger-ahead/

about NBTs-based food, showing that limited familiarity together with concerns about their naturalness can explain why consumers prefer more traditional products. Their study also explains that acceptance is higher when consumers perceive tangible benefits, such as nutritional value or more sustainable production processes.

In analysing the aversion to biotechnology, Lusk *et al.* (2018), explored the main causes of heterogeneity in consumer preferences for GE food and food policies by determining consumers' acceptance of GE foods or plant breeding technologies. Their results highlight the presence of small differences in consumer preferences for policies related to different plant breeding methods. However, consumers support the idea that GE food products should be regulated based on risk analysis of their impact on health and the environment rather than the process used to create new varieties. Support or opposition for GE food depends as well on public trust in technology developers (Lucht, 2015; Siegrist *et al.*, 2012). Other authors pointed out that one of the relevant obstacles in the public acceptance of GM and GE is related to information received by consumers from the media, internet, and other sources (Ishii, Araki, 2016; Lucht, 2015; Wunderlich, Gatto, 2015).

Consumer acceptance is also affected by several factors which include ethical and cultural values as well as health concerns (Lusk, Coble, 2005; Costa-Font *et al.*, 2008). As specified in the empirical literature, consumer knowledge on this topic is limited due to a lack of consumer education. Marette *et al.* (2020), in analysing the willingness to pay for GE/GMO apples in Europe and the US, showed a tangible concern for GE/GMO varieties in both areas, with French consumers raising more concerns in comparison to the US, and preferring more information. Other studies reported that limited knowledge and biased information make consumers incapable of correctly evaluating what concrete risks associated with these products (Siegrist, 2008; McFadden, Lusk, 2016). Fernbach *et al.* (2019), demonstrated that inadequate knowledge on science and genetics generates a major opposition to GM foods, while lesser negative judgments are correlated with a higher knowledge level on GM products. However, some of the literature suggests that consumers are more likely to accept GM food if they recognize some tangible benefit such as reduction in the use of pesticides (Lusk *et al.*, 2015; Gaskell *et al.*, 2003) or other environmental benefits (Delwaide *et al.*, 2015; Lusk *et al.*, 2004; Gaskell *et al.*, 2003). In addition, scholars also find that if new technologies improve nutritional content, then they become more acceptable (Lusk *et al.*, 2015; Lusk *et al.*, 2004; Grunert *et al.*, 2001; Pham, Mandel, 2019). People also positively evaluate the fact that NBTs could contribute to food security in developing economies (Lusk *et al.*, 2004; Hossain *et al.*, 2003).

Hence, adequate information allows consumers to change or re-address their opinions. In this perspective, the interesting works by Siegrist (2008), Lusk *et al.* (2015), Pakseresht *et al.* (2017) and Edenbrandt *et al.* (2018), emphasize that consumers may increase their preferences and willingness to pay for GM food alternatives when information is provided about health, nutrition, and environmental benefits. De Marchi *et al.* (2020), explore the role of information in affecting consumers' preferences for food products in the case of cisgenic versus conventional apples, demonstrating that information on health-related benefits, particularly environmental benefits, contributes to generating a positive and favourable opinion on cisgenic food. Recently Ferrari *et al.* (2020), investigated students' attitudes towards GE food in the Netherlands and Belgium and found that they were determined by environmental concern (negative) and objective knowledge (positive). Key factors influencing preferences for GE labelling were a non-hard-scientific background, knowledge about relevant policies and a negative attitude towards GE food (Ferrari *et al.*, 2020). A recent review of selected articles published in the last 16 years (2005-2021) assesses that public knowledge of GM technology and products remains the main factor concerning general attitude and acceptance, followed by socioeconomic factors, trust in public authorities and regulations, media, and communication (Hermosaningtyas, 2021).

Recently, Marangon *et al.* (2022) conducted a choice experiment to investigate Italian consumers' preferences for bread made with gene-edited wheat. Results demonstrate that consumers do not know very much about breeding techniques, therefore it is suggested to develop better communication strategies for society to comprehensively understand biotechnologies and support policymakers in the definition of informed regulations.

This brief literature review shows that there is still some reluctance with respect to GM and GE as consumers don't fully trust them and are not fully aware of their potential benefits. Nevertheless, consumers' behaviour is not homogenous worldwide, with European consumers showing a higher level of skepticism. Consumer non-acceptance of enabling agri-food technologies and their products, including genetic modification, is an important barrier to their commercialization (Frewer, 2017).

Our study has a twofold objective: first, we explore consumers' attitudes towards genetically modified food; second, we determine how potential consumers assimilate scientific information on NBTs in making an ex-post opinion after receiving information. Our analysis focuses on a specific segment of consumers made by university students. The so-called Millennials are being investigated by several scholars (Bollani *et al.*, 2019; Oz *et al.*, 2018; Cavaliere, Ventura, 2018; Coderoni, Perito, 2021; Ferrari *et al.*, 2021) to explore the possible generational shift in attitudes and purchasing decisions. Millennials are considered more informed than others with respect to the environment and also more concerned about the environment and the ethical attributes of products (Cavaliere, Ventura, 2018).

Individuals' decisions whether to support or oppose GM crops are made under uncertainty. According to the Bayesian decision theory, when deciding under uncertainty, individuals combine a prior belief with new information to form an ex-post belief. Under the Bayesian theory, individuals process information optimally and converge to the new information received. In doing so, individuals allocate weights to prior beliefs and new information. The first hypothesis this work wants to test is whether exposure to scientific information changes the perception of consumers' information on GM. People elaborate new information received and converge to it (McFadden, Lusk, 2015; De Marchi *et al.*, 2022; Son, Lim, 2021).

In reality, ex-post beliefs do not always converge to information for several reasons. If people's behaviour does not converge towards the scientific information received, it means that higher weight is attributed to the prior belief, e.g., there is some form of prejudice. In the case of GM foods, there is apparently a disconnection between scientists' opinions and public opinion. These forms of violation of the Bayesian decision theory are defined as cognitive bias. According to Jang (2014) individuals with higher levels of perceived knowledge about GM are more likely to converge to information.

The second hypothesis of this study refers to the confirmation of prior beliefs. Current beliefs prevail in formulating opinions that diverge from the new information received (Grunert *et al.*, 2003; McFadden, Lusk, 2015; Fernbach *et al.,* 2019; Pham, Mandel, 2019). The reason could be that many people do not receive or accept scientific information, or it could be that they place greater weight on other types of non-scientific information (McFadden, Lusk, 2015). In making their opinion, consumers may take into consideration several concerns such as the unexpected damages of GM crops/food to the environment, destruction of biological diversity, food safety concerns, religious and moral problems. Wuepper *et al.* (2018), with respect to German consumers, found that attitudes seem to mostly reflect fundamental preferences. Some authors think that scientific research data are often intentionally marginalized when reporting science, while media attention on specific issues can be unbalanced and selective (Curtis *et al.*, 2008; Malyska *et al.*, 2016; McCluskey, Swinnen, 2011). Despite all the scientific findings, consumers still have disbelief about accepting the new information received and tend to confirm their prior beliefs.

The third hypothesis states that people having a higher knowledge tend to confirm their prior beliefs. Consumer knowledge can be distinguished between perceived and actual knowledge, that is between what consumers think they know and what they really know. As a consequence, there might be an underestimation of the knowledge level that may affect consumers' attitudes and behaviours (Fernbach *et al.*, 2019; Jang, 2014; McFadden, Lusk, 2015; McFadden, Lusk, 2016; Huffman *et al.*, 2007; Hwang, Nam, 2021).

The following section describes methodology details. The model description is in section 3. The discussion of the results is presented in section 4, while section 5 concludes.

2. RESEARCH METHODOLOGY AND DATA

a. Questionnaire and data gathering

To address our research questions, we developed two different tools: a questionnaire and a five-minute video in collaboration with scientists, designed to familiarize respondents with different breeding technologies used for different crops and objectives. Both instruments were tested in a pilot study and then submitted through an online survey.

Links to the online tools were sent to professors teaching in 15 universities selected to have a balanced distribution in terms of geographical area and academic subjects, thus including humanities, social sciences, and scientific disciplines). The professors submitted the tools to both their first degree and the master's degree classes, during the academic year 2019/2020.

The number of individuals who responded to the questionnaire was 506. Sixty-one percent of the survey sample was comprised of females, 25% held a Bachelor's degree and were enrolled in a Master's degree.

Descriptive statistics of the sample are illustrated in Table 1.

The questionnaire was divided into 6 sections as described in Figure 1. The first section regarded demographic questions. In the second section – the self-assessment of knowledge – respondents were asked if and how much they know about genetic techniques. In the third section, ten questions were submitted to verify

Tab. 1. Descriptive statistics of respondents.

Gender	Freq.	Percent
Male	197	*38.93*
Female	309	*61.07*
Total	506	*100*
Faculty	**Freq.**	**Percent**
Humanities and Social Science	28	*5.5*
Economics	108	*21.3*
Engineering and Medical Studies	52	*10.28*
Agricultural Science, Biological Science and Biotechnology	318	*62.8*
Total	506	*100*
University Degree	**Freq.**	**Percent**
First Degree	380	*75.1*
Master	126	*24.9*
Total	506	*100*

the real level of knowledge. The fourth section contained direct questions to verify the willingness to purchase GM products and concerns about perceived risks in the two areas previously described i.e., food safety and environmental risks. Both categories of risk represent societal concerns i.e., potential damage for the population. Societal concern refers to hazards with the capability of generating socio-political responses (Ball, Boehmer-Christiansen, 2007). Drivers can be intrinsic as a genuine predictable risk but also based on ethical considerations, lack of trust or particular groups activities (Morgan, Henrion, 1990). In the fifth section, we asked some questions related to the desired governance level for NBTs e.g., at what level should authorization or labelling be regulated. Between the fifth and sixth section, students had to watch a 5-minute video where scientific information was provided by biotechnologists participating in the same research project. After watching the video students were again asked the questions already posed in the third section in order to check the changes in their willingness to purchase and in perceived risks after having received some "easy to digest" information based on scientific evidence. A brief overview of the questions asked is described below[2].

b. Variables construction

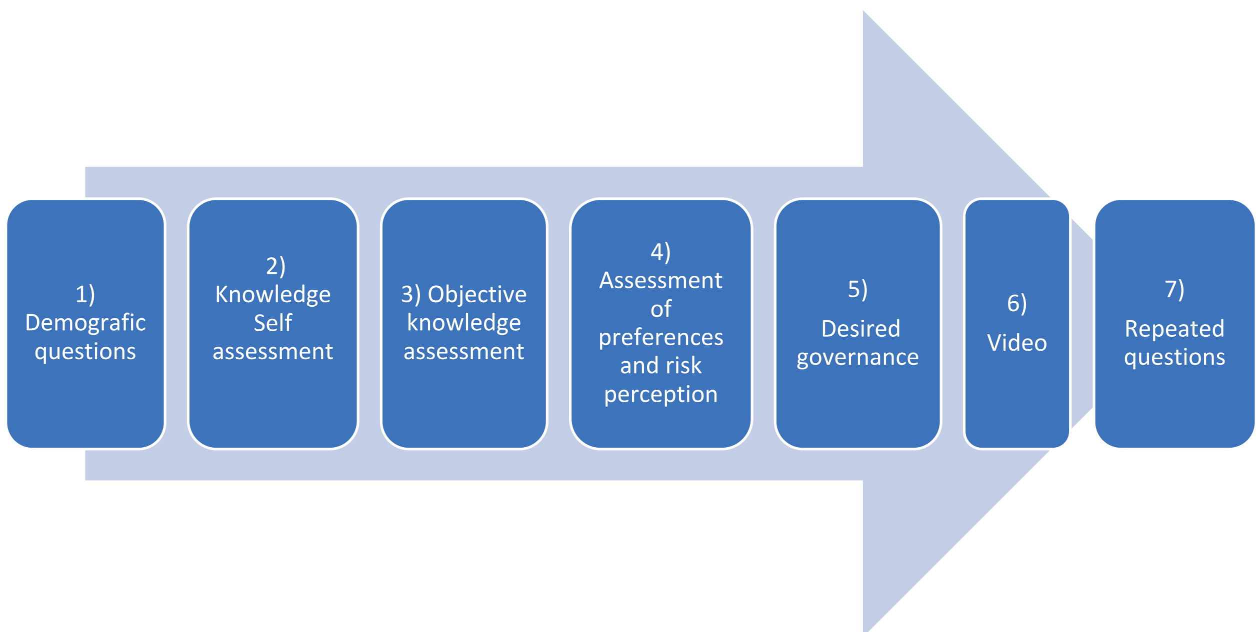
Based on the responses to the questionnaire, we built several variables.

From the demographics we obtained two variables: *Gender* and the *Study Field* (1= Humanities and Social Sciences; 2: Economics; 3: Engineering and Medical Schools; 4: Agricultural Science and Biotechnology).

The *Perceived Knowledge* variable is the result of the self-assessment of knowledge on GM food (2nd section). Similarly, to McFadden and Lusk (2014) questions to determine subjective knowledge about GM food ranged

[2] Questionnaire available in the complementary material.

Fig. 1. Details of the online survey.



on a five-point scale from "Very Unknowledgeable" to "Very Knowledgeable".

In the third section, a group of ten questions were posed to determine how much the students really knew about GM crops. Questions regarded specific breeding techniques, the proportion of maize and wheat areas planted with GM seed or which GM crops were available on the market, if they could be sold in Italy and other questions with Yes/No answers. Then, according to the score from the ten answers we created a new variable denominated *Actual Knowledge*, split into four levels according to increasing levels of knowledge about GM crops/foods and regulatory issues. Additionally, we computed the gap between actual and perceived knowledge for each individual and created a variable named *Change_k*.

In the fourth section we asked if "Food that has genetically modified ingredients is safe to eat" and if "Growing genetically modified ingredients is safe for the environment". The risks regarding food safety or the environment represent two forms of possible negative outcomes associated with GM crops/foods.

We used a set of four answers (from "strongly disagree" to "strongly agree") to measure opinions about the two potential risks and included an "I do not know" option. In both cases, we asked a question that measured confidence in the response to the previous agreement question.

The responses obtained from the fourth section of the questionnaire related to the willingness to purchase GM products and concerns about perceived risks in the two areas previously described i.e. food safety and environmental risks were elaborated to create a *prior belief variable*.

Participants were classified in three groups for each risk category (food safety or environment):

- *Believers*: Participants who believe GM foods are safe to eat or do not cause environmental damage (answers *I agree,* and *I strongly agree*);
- *Denier*s: Participants who deny GM foods are safe to eat or can cause environmental damage (answers *I do not agree* and *I somewhat do not agree*);
- *Neutral*s: Participants who neither believe nor deny GM foods are safe to eat or can cause environmental damage (answer *I don't know*).

In the fifth section we asked about the preference for mandatory labelling and which authority should take such decisions. Accordingly, to the answers to the two questions on the preferred level of governance (EU, State, Region) we created a dummy variable (*EU-centric*).

In the last section, the questions in section 3 were repeated.

Based on the observed changes people were classified in the following three groups:

a. *Conservative:* when the individual kept their initial opinion according to the new information;
b. *Convergent*: when the individual changed their initial opinion according to the new information;
c. *Divergen*t: when the individual changed their initial opinion contrary to the new information.

Statistical details are in Table 2.

Table 2 shows the descriptions and means of explanatory variables used in econometric analysis. The model was estimated using 506 observations, the number of respondents to the survey.

The Chi-square test of independence[3] was used to test the association of "knowledge" variables with those regarding the study field and gender (Tab. 3). For two of the four variables' pairs tested we obtained a dependent relationship. There was a significant association between perceived knowledge and study field on the one hand, and actual knowledge and study field on the other.

3. EMPIRICAL MODEL

In the study, we want to understand the effects of subjective prior beliefs on the acceptance of scientific information. As anticipated in the introduction, people may trust the information that they have received (Bayesian hypothesis) or they can distrust it assigning more weight to their prior belief. According to Jang (2014), which examined whether participants chose to read scientific information that confirmed or contradicted a prior belief, a high level of perceived knowledge can cause people to confirm a prior belief.

Given that the dependent variable is not specified in any order of importance or magnitude, this study used an unordered Multinomial Logit Model (MNL) in modelling the information-processing outcome categories. We estimate two MNLs, one for each category of societal risk for which prior and ex-post beliefs were investigated with the survey.

The dependent variable for the model is a discrete variable taking a value ranging between 0 and 2 (*Conservative* information = 0; *Convergent* = 1, *Divergent* = 2).

We tested for the following hypothesis:

H0: Bayesian hypothesis (people converge to the information received) i.e. individuals process information optimally and converge to the new information received;

H1: Some people violate the Bayesian decision theory confirming a prior belief that diverges from the new information received (confirmation bias);

[3] Test of Independence only assesses associations between categorical variables and cannot provide any inferences about causation.

Tab. 2. Descriptions and means of variables used in logit model estimations.

Variables names	Description	Value	Food safety Mean	Environment Mean
Info_process	**Dependent variable**: Conservative, Convergent, or Divergent	Variable ranging from 0 to 2		
Believers	Respondents who believe GM products do not present additional risks for food safety or the environment	Variable coded 0/1	0.523	0.227
Neutrals	Respondents who don't have an opinion on GM products presenting additional risks for food safety or the environment	Variable coded 0/1	0.233	0.138
Deniers	Respondents who believe GM products do present additional risks for food safety or the environment	Variable coded 0/1	0.243	0.634
Perceived_K	Level of presumed knowledge in the field of genetic breeding techniques	Score ranging 1 (no knowledge) to 4 (optimal knowledge)	2.474	2.474
Actual_K	Level of objective knowledge on scientific information on GM crop/food.	Variable ranging from 1 (no knowledge) to 6 (optimal knowledge)	3.333	3.333
Change_K	Difference between actual knowledge on scientific information on GM crop/food and perceived knowledge	Variable ranging from 1 to 5	2.867	2.867
EU-centric	Dummy accounting for the effects of regulating biotechnology	Variable coded 0/1	1.612	1.612
Gender	Dummy variable equal to 1 for female and 0 for male.	Variable coded 0/1	0.610	0.6103.302
Faculty	Study field	Variable ranging from 1 to 4 Coded =1 for Humanities and Social Sciences 2= Economics; 3= Engineering and Medical Schools. 4= Agricultural Science and Biotechnology,	3.302	3.302

Table 3. Chi-square values and significant levels of variables pairs.

Variables	Chi-square	Degree of freedom	Significance level
Perceived knowledge/study_field	42.764	12	0.000*
Actual knowledge/study_field	29.087	8	0.000*
Perceived knowledge/gender	6.817	3	0.103
Actual knowledge/gender	2.431	2	0.297

Note: Significance at 0.05.

H2: People who have a higher knowledge tend to confirm their prior belief (they are more skeptical towards new information).

The Logit model for multiple choice problems takes the following form:

$$Pr\{Y_i = j\} = \frac{\exp\,(x_i\beta_j)}{1+exp\{x_i\beta_2\}+exp\{x_i\beta_3\}+\cdots+exp\{x_i\beta_M\}};\, j = 1,2 \ldots M \quad (1)$$

Where x_i is a K-dimensional vector containing the characteristic s of individual i (including an intercept term) and β_j denotes a vector of alternative-specific coefficients. We estimate K-1 slope coefficients plus an intercept term for all but one of the alternatives.

Caution must be used in interpreting the Multinomial Logit coefficients, as their significance depends on the chosen baseline outcome category that determines which specific log odds ratio is estimated. Therefore, the coefficients and estimated standard errors will change according to the chosen baseline category because they are related to the number of observations in the two appropriate categories. If a baseline category includes few observations, then the standard errors could be higher for all associated coefficients. However, the choice of the baseline does not affect the predicted probability and their standard errors. This problem can be overcome through the use of marginal effects (Scott-Long, 1997; Paolino, 2021).

The marginal effects in this model are the effect of changing a regressor by one unit on the probabilities of choosing each alternative:

$$\frac{\partial \Pr\,(Y_i=j)}{\partial x_i} = \Pr(Y_i = j|x)\left(\hat{\beta}_{jk} - \sum_{j=1}^{M}\hat{\beta}_{jk} * \Pr\,(Y_i = j|x)\right) \quad (2)$$

The term $\left(\hat{\beta}_{jk} - \sum_{j=1}^{M} \hat{\beta}_{jk} * \Pr\left(Y_i = j|x\right)\right)$ signs the marginal effects, it is possible to observe that the sign of the marginal effects may or may not correspond to the sign of the coefficient estimated itself.

4. RESULTS AND ROBUSTNESS TESTS

Approximately 52.37% of the sample considered that GM food is safe to eat prior to receiving information, approximately 23.32% were unsure, and the remaining 24.31% did not consider GM foods as safe. Regarding environmental risk, approximately 22.73% of the sample considered GM production safe, approximately 13.83% were not sure, and the remaining 63.44% did not consider it risk-free. Therefore, participants' perception of risk was higher in the case of potential environmental damage with respect to food safety.

Relative frequencies of prior beliefs and ex-post beliefs for both societal risks are reported in Table 4 and 5.

The first objective of our analysis was to determine if information processing was dependent on prior beliefs. As described previously, students were given the same questions after receiving the new information in order to check if they had changed their prior beliefs and formed new ex-post beliefs.

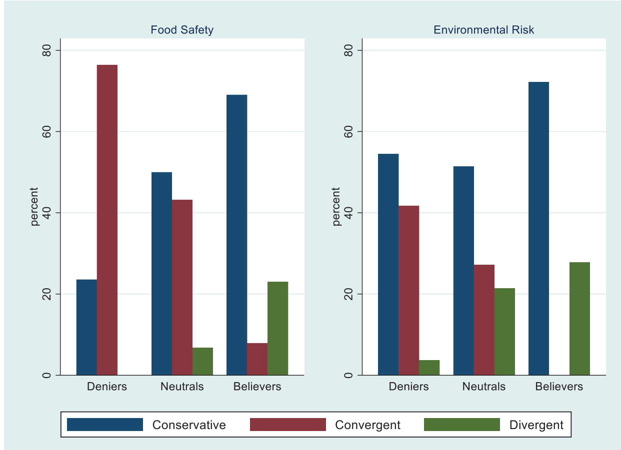
Tab. 4. Descriptions and relative frequencies of prior beliefs.

Food safety	Freq.	Percent
Believers	265	*52.37*
Neutrals	118	*23.32*
Deniers	125	*24.31*
Total	506	*100.00*
Environment		
Believers	115	*22.73*
Neutrals	70	*13.83*
Deniers	321	*63.44*
Total	506	*100.00*

Tab. 5. Descriptions and relative frequencies of information processing categories.

Food safety risk	Freq.	Percent	Cum.
Convergent	200	*39.52*	*39.53*
Conservative	212	*41.90*	*81.42*
Divergent	94	*18.58*	*100*
Total	506	*100*	
Environmental risk	**Freq.**	**Percent**	**Cum.**
Convergent	102	*20.16*	*20.16*
Conservative	258	*50.99*	*71.15*
Divergent	146	*28.85*	*100.00*
Total	506	*100*	

Fig. 2. Assimilation of scientific information on Food Safety and Environmental Risks.



Ex-post beliefs with respect to both types of risks were tested to be dependent on *prior beliefs* (Person's Chi squared test <0.05). Figures 2 illustrates how interviewed students with different prior beliefs assimilate scientific information on GM foods with respect to their beliefs on food safety and environmental risk.

When considering the food safety issue, a student in the *Believers* category is more likely to be in the conservative group, not changing his/her opinion. A small group of students converged after receiving information, while others diverged. The majority of people who were categorized as deniers, on the other hand, converged to information. This implies that the new information prevailed over prior beliefs. Finally, students in the Neutral category are more likely to be either in the convergent or conservative categories, and least likely to be in the divergent one. This indicates that students who previously were unconcerned about food safety either hold their prior belief or align with information while only a few did not align with the information received.

We obtain a different pattern of results where the risk for the environment is concerned. Again, participants in the *Believers* grouping are more likely to be conservative, not changing their prior belief. Students who previously believed that GM production was unsafe for the environment e.g., students in the *Deniers* outcome, are instead split between the convergent and conservative groups with a majority in the last category where the prior belief prevails. Finally, students in the

Tab. 6. Marginal effects in the food safety model.

	conservative		convergent		divergent	
	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Believers	0.217	0.056***	-0.357	0.053***	0.140	0.025***
Deniers	-0.127	0.065**	0.280	0.063***	-0.156	0.018***
Perceived_k	0.086	0.035**	0.009	0.029	-0.096	0.024***
Change_k	0.033	0.027	0.021	0.022	-0.055	0.019**
Education	0.090	0.046**	-0.058	0.037	-0.031	0.031
Gender	-0.021	0.043	0.043	0.035	-0.022	0.030
EU_centric	-0.024	0.041	-0.023	0.034	0.047	0.029

Estimates are from Multinomial logit using 506 observations. Standard Errors in parenthesis. * Indicates statistically significant at 10% level. ** Statistically significant at 5% level. *** Statistically significant at 1% level.

Neutral category, move towards the conservative and convergent group.

Our second objective was to test the three hypotheses about information processing. To this extent we assumed the information-processing outcome categories (conservative, convergent and divergent) as dependent variables. Table 6 presents marginal effects with regard to consumers' beliefs towards the food safety issue, while Table 7 reports the marginal effects as concerns consumers beliefs about the environmental risks linked to GM crops[4]. Robustness checks are discussed below.

When considering the risk associated with food safety, interviewed students who had been classified as *believers* behave in a conservative way while those classified as *deniers on the basis of their prior belief* show a higher probability of being convergent. Therefore, in both cases, the Bayesian Hypothesis (H0) holds, i.e., people converge to the new information. Our findings in comparison to McFadden and Lusk (2015) show that people classified as deniers were less likely to be divergent. In the same case people keep their original belief (deniers conservative or divergent significant). This result suggests that the H1 holds. The variable *Change_k* is significant and negative in the divergent group and conversely, positive, and significant in the conservative outcome. These results show that, in the case of food safety, people who realize that their knowledge is limited are more willing to change their previous ideas and converge to scientific information[5], confirming the Bayesian hypothesis H0.

The variable *perceived_k* is positive and significant in the conservative outcome and negative in the convergent and divergent one, whereas participants with a higher level of perceived knowledge are more likely to suffer from cognitive bias. This result is similar to Jang (2014) who showed that people having a high level of perceived science knowledge are more likely to read scientific information and confirm a prior belief. In the same vein, we also found that students enrolled in scientific degrees are more likely to be in the conservative group trusting their own knowledge, i.e., H2 holds.

The variable related to the preferred level of governance (*EU-centric)* is not significant for all the outcomes. Finally, no gender effect has been detected.

The second model regards students' beliefs about environmental risks linked to cultivation of genetically modified crops. In this case, relative to participants in the neutral group, believers were more likely to be conservative while deniers were more likely to be divergent. This means that they all gave a higher weight to their prior beliefs. H0 is rejected for participants classified as deniers and in this case H1 holds.

Both knowledge variables, the one regarding self-assessment and the change between perceived and actual knowledge, are positive and significant in the conservative model; the finding suggests that people who (wrongly) consider knowing more about biotechnologies are more likely to suffer from information bias and do not converge to new information they receive from a scientific source, i.e., H2 is confirmed. Again, students enrolled in science degrees show a negative and statistically significant marginal effect in the convergent group. In this case the prior belief is not changed by the new information received, confirming H2.

[4] It is important to keep in mind that the marginal effects of a Multinomial Logit refer to changes in the probability of one outcome, while raw coefficients to the ratio of log probability of one outcome and the probability of baseline outcome. A variable can affect one probability and the baseline probability and positively impact on the ratio, but negatively affect the one probability (https://stats.stackexchange.com/users/23853/maarten-buis).

[5] We run a MNL by considering the variable actual knowledge (*actual_k*) in place of *change_k*. Our findings are similar to those of McFadden and Lusk (2015), which indicated that people with a high level of scientific knowledge tend to be conservative.

Tab. 7. Marginal effects in the environmental risk.

	conservative		convergent		divergent	
	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Believers	0.313	0.044***	-0.353	0.024***	-0.040	0.399
Deniers	-0.053	0.055	0.130	0.044 **	-0.184	0.044***
Perceived_k	0.073	0.037*	-0.037	0.032	-0.036	0.018
Change_k	0.053	0.028*	-0.022	0.023	-0.031	0.026*
Education	0.008	0.045	-0.071	0.040 *	0.030	0.029
Gender	-0.040	0.047	-0.037	0.038	-0.046	0.028
EU centric	-0.057	0.043	-0.107	0.037**	0.049	0.027*

Estimates are from Multinomial logit using 506 observations. Standard Errors in parenthesis. * indicates statistically significant at 10% level. ** statistically significant at 5% level. *** statistically significant at 1% level.

The gender variable is not significant.

Figures 3 and 4 show the median and distribution of students' predicted probabilities of information process for each category, across deniers (Fig. 3) and believers (Fig. 4). Note that there are large differences between believers on the probabilities for conservative and convergent, and smaller ones for divergent.

To test the robustness of our estimates, several models were run introducing new independent variables. Firstly, we used *actual_k* in place of *change_k*; secondly, we considered an interaction term between *perceived_k* and *believers* on the one hand; and *perceived_k* and *deniers* on the other. Results from the robustness check confirm our findings[6].

Furthermore, we verified whether the models fit the data by looking to the Global likelihood ratio test. This equals -369.360 in the food safety model and -393.701 in the environmental risk model, indicating that in both models we can reject the null hypothesis with a high degree of confidence. We also conducted a LR and Wald test to investigate whether specific variables have effects, either singly or jointly, for each independent variable. Both tests led to very similar conclusions. In the food safety model, we found that believers, deniers, perceived knowledge, changes in knowledge and faculty effects are significant; therefore, rejecting the hypothesis that these variables do not affect the value considered important for the information process[7] (Tab. 8). We conducted a Wald test for each independent variable and the result was similar to LR test. We also tested for the property of independence of irrelevant alternatives (IIA). This stringent assumption of the Multinomial Logit requires

Fig. 3. In-Sample Predicted Probabilities, by deniers (Boxplots).

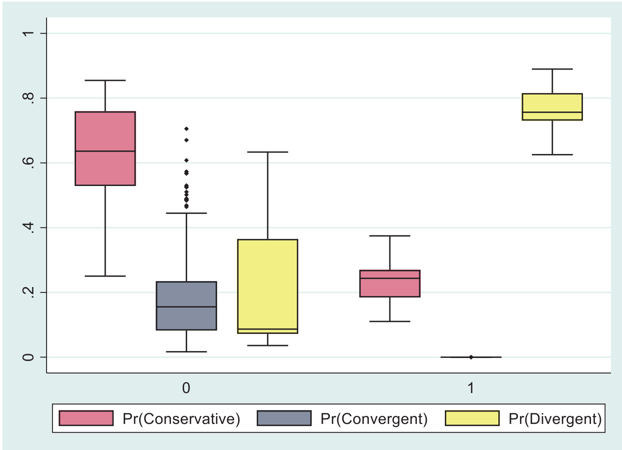
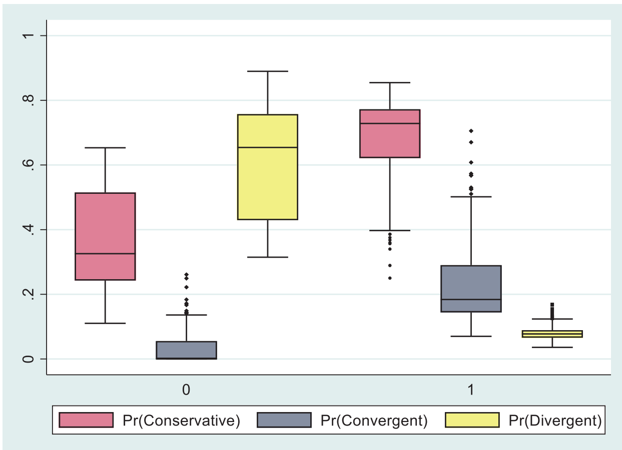


Fig. 4. In-Sample Predicted Probabilities, by believers (Boxplots).



[6] Results are not reported in the study, but they are available upon request.

[7] The variable's effects on believers, deniers, perceived knowledge, changes in knowledge are significant at 5%, while faculty at 10%.

Tab. 8. LR tests for independent variables (N=506) in the food safety model.

	chi2	df	P>chi2
Deniers	34.238	2	0.000 (*)
Believers	64.479	2	0.000 (*)
Perceived_k	13.028	2	0.001 (*)
Change_k	8.228	2	0.016 (*)
Study_field	5.233	2	0.073 (*)
Gender	1.742	2	0.419
EU centric	2.793	2	0.247
Info	0.121	2	0.941 (*)

Tab. 9. LR tests for independent variables (N=506) in the environmental risk model.

	chi2	df	P>chi2
Deniers	23.262	2	0.000 (*)
Believers	0.009	2	0.996
Perceived_k	3.483	2	0.175
Change_k	3.786	2	0.151
Study_field	0.914	2	0.633
Gender	2.430	2	0.297
EU centric	8.755	2	0.013 (*)
Info	0.310	2	0.856

that the inclusion or exclusion of categories does not affect the relative risks associated with the regressors in the remaining categories (Long and Freese, 2014). The results of the test confirm that IIA has not been violated.

In the environmental risk model, we detected significant effects for believers and deniers at 1%. The Wald test confirmed the significant effect of deniers and EU regulation. The results of the test also in the environmental risk model confirm that IIA has not been violated (Tab. 9).

We validated the classification model by using a confusion matrix, accuracy test and error rate (ER). The overall accuracy demonstrates a performance equal to 84% with an error value equal to 15.6% for the consumption model and 57.9% with an ER of 42%. Results of the ACC, which is the probability of performing a correct classification, show a high probability for the consumption model. Details are provided in the Appendix.

5. DISCUSSION AND CONCLUSIONS

Although scientists consider NBTs as a set of technologies that can overcome some of the criticism associated to transgenics techniques, at the same time addressing many challenges linked to sustainable intensification in agriculture, most people do not distinguish between the two approaches and still maintain relevant prejudice on the commercial use of NBTs. These cognitions may change over time as reported by Van Giesen, Fischer and van Trijp (2018). Whereas at the beginning of the technological innovation process, people rely relatively more on affect or emotional responses, later on reliance on cognition increases.

In this paper, we have investigated Italian university students' concerns with regard to food products obtained using New Breeding Techniques. We surveyed a sample of 506 Italian students online belonging to 15 universities, asking them questions on food safety and environmental risk. The majority of these students declared to be unaware or have a very limited knowledge of GM techniques. Testing their real knowledge, we were able to check that in many cases they overestimated their knowledge on GM crops. Providing people with new information on the use of NBTs it is therefore important to allow them to make an unbiased judgment on NBTs.

Nevertheless, students showed concerns about potential risks associated with GM crops consumption and cultivation. Initially, 55% and 63% of those interviewed declared that GM food would represent a problem for food safety or for the environment. Once new information was provided from scientists, students who had concerns about food safety significantly converged to the new information received, changing their prior belief. In the case of environmental risk this process of convergence towards the new information received was lower and many students significantly diverted from the information, revealing the existence of a prejudice that did not allow them to change their original opinion i.e., people assign a higher weight to their prior beliefs. This result confirms the Grunert *et al.* (2003) finding on people's beliefs about risks as embedded in more general attitudes towards nature. This result can also be influenced by the specific target of our analysis, as millennials are considered in the literature more concerned about the environment and the ethical attributes of products (Cavaliere, Ventura, 2018). Higher environmental concern with regard to cisgenesis was also found by De Marchi *et al.* (2021), in the case of "future-oriented" consumers in Italy who perceived the technology as rather unnatural and potentially risky.

Our results also confirm De Marchi *et al.* (2022) which demonstrated that information on health-related and, especially, on environmental benefits contribute to generating a positive communication landscape around cisgenic food.

This result, in our opinion, gives an important hint to researchers about where to address communication when disseminating their findings to the general public in order to gain public support for legislative changes allowing the cultivation of crops obtained through the use of NBTs. According to these results, communication on new breeding techniques should carefully address people's concerns on potential environmental impacts to avoid consumer rejection of NMTs. Scientists should therefore disseminate their research results not only to the research arena but to policy-makers and a wider audience given the existing lack of knowledge of the general public, explaining what NBTs are and their potential benefits. In this respect, our study contributes to the literature by adding new information on a specific consumer segment (students) preferences for NBTs, providing evidence about their lack of knowledge of these techniques. The study also informs on which are the perceived potential risks and how the respondents process information to change or maintain their opinion. Our results showed that people with a higher level of knowledge on biotechnologies, such as students in the scientific area, are more likely to confirm their prior belief and in the case that they initially have a negative attitude, they do not converge to the information received showing a confirmation bias.

Knowing societal preferences is also relevant in order to implement research strategies in line with stakeholders' priorities. Addressing stakeholder priorities and preferences in the technological innovation process is considered crucial for implementing an effective commercialization trajectory for new technologies (Raley *et al.*, 2016).

One main limitation of our study is the fact that our sample of university students might not be representative of the Italian student population, mainly in terms of academic background. A second limitation regards the kind of information received. Here we provided a short video on GM techniques and their potential benefits, but future research may provide new insights related to different kinds of information that could be more influential.

Although this approach provides some advantages, because it limits the possible bias from unobserved heterogeneity and provides a homogeneous population, further investigation is needed to confirm the generality of the research's result.

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APPENDIX

Tab. A.1. Beta coefficient from food safety risk.

	β Conservative	SE	β Convergent		β Divergent	
0						
1.believers			1.924***	(0.310)	-1.242**	(0.430)
1.denier			-1.389***	(0.298)	14.93	(807.2)
perceived_k			0.137	(0.211)	1.056***	(0.248)
change_k			-0.0713	(0.161)	0.566**	(0.192)
1.EU_centric			0.0459	(0.243)	-0.510	(0.294)
1.female			-0.230	(0.252)	0.251	(0.290)
_cons			0.196	(0.914)	-1.829	(1.053)
1						
1.believers	-1.924***	(0.310)			-3.165***	(0.486)
1.denier_cons	1.389***	(0.298)			16.32	(807.2)
perceived_k	-0.137	(0.211)			0.919**	(0.304)
change_k	0.0713	(0.161)			0.637**	(0.233)
1.EU_centric	-0.0459	(0.243)			-0.556	(0.356)
1.female	0.230	(0.252)			0.481	(0.358)
_cons	-0.196	(0.914)			-2.025	(1.272)
2						
1.believers	1.242**	(0.430)	3.165***	(0.486)		
1.denier_cons	-14.93	(807.2)	-16.32	(807.2)		
perceived_k	-1.056***	(0.248)	-0.919**	(0.304)		
change_k	-0.566**	(0.192)	-0.637**	(0.233)		
1.EU_centric	0.510	(0.294)	0.556	(0.356)		
1.female	-0.251	(0.290)	-0.481	(0.358)		
_cons	1.829	(1.053)	2.025	(1.272)		
N	506		506		506	

Estimates are from Multinomial logit using 506 observations. Standard Errors in parenthesis. * Indicates statistically significant at 10% level. ** statistically significant at 5% level. *** statistically significant at 1% level.

Tab. A.2. Beta coefficient from environmental risk.

	β Conservative	SE	β Convergent	SE	β Divergent	se
0						
1.believers			16.42	(616.3)	-0.00848	(0.396)
1.denier			-0.526	(0.315)	1.788***	(0.441)
perceived_k			0.343	(0.179)	0.381	(0.253)
change_k			0.191	(0.137)	0.357	(0.204)
1.EU_centric			0.517*	(0.216)	-0.407	(0.313)
1.female			-0.125	(0.223)	0.409	(0.304)
_cons			-0.783	(0.778)	-1.035	(1.105)
1						
1.believers	-16.42	(616.3)			-16.43	(616.3)
1.denier	0.526	(0.315)			2.314***	(0.475)
perceived_k	-0.343	(0.179)			0.0378	(0.287)
change_k	-0.191	(0.137)			0.167	(0.227)
1.EU_centric	-0.517*	(0.216)			-0.924**	(0.356)
1.female	0.125	(0.223)			0.534	(0.350)
_cons	0.783	(0.778)			-0.252	(1.221)
2						
1.believers	0.00848	(0.396)	16.43	(616.3)		
1.denier	-1.788***	(0.441)	-2.314***	(0.475)		
perceived_k	-0.381	(0.253)	-0.0378	(0.287)		
change_k	-0.357	(0.204)	-0.167	(0.227)		
1.EU_centric	0.407	(0.313)	0.924**	(0.356)		
1.female	-0.409	(0.304)	-0.534	(0.350)		
_cons	1.035	(1.105)	0.252	(1.221)		
N	506		506		506	

Estimates are from Multinomial logit using 506 observations. Standard Errors in parenthesis. * Indicates statistically significant at 10% level. ** statistically significant at 5% level. *** statistically significant at 1% level.

Confusion matrix Results

The confusion matrix allows relations between the classifier outputs and the true ones to be observed; indeed, it reports the classification errors. The elements in the diagonal are those correctly classified, while the elements out of the diagonal are misclassified.

TP refers to True positive, FN indicates False negative; TN denotes True negative and FP False positive. TP refers to the number of predictions where the classifier correctly predicts the positive class as positive. TN indicates the number of predictions where the classifier correctly predicts the negative class as negative. FN indicates the incorrectly predicted positive class as negative (rejected data for classes). It is the sum of the values in corresponding rows excluding the TP values. FP refers to the incorrectly identified negative values as positive. It is the sum of the values in corresponding columns excluding the TP values.

Tab. A.3. Mlogit Confusion Matrix.

		Predict		
		A	B	C
Actual	A	TRUE	FALSE	FALSE
	B	FALSE	TRUE	FALSE
	C	FALSE	FALSE	TRUE

The accuracy on the classification (ACC) and error rate are the two more common parameters used for reporting the performance of the model. The ACC is the probability of performing a correct classification:

$$ACC=TP/ (TP+TN+FP+FP)$$
$$Error\ rate=(1-ACC)$$

The overall accuracy demonstrates a performance equal to 84% with an error value equal to 15.6% for

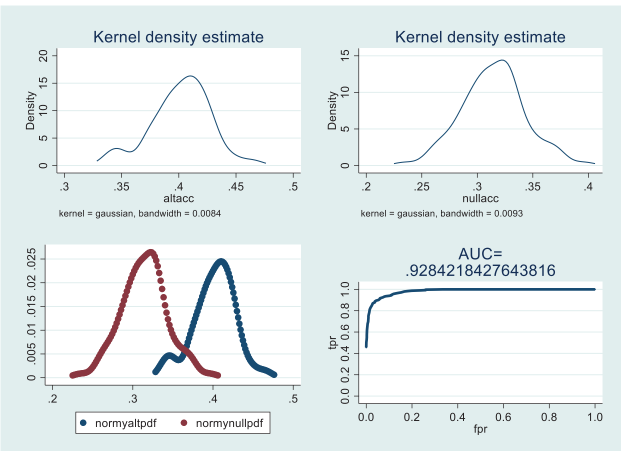
Tab. A.4. Confusion Matrix for Food Safety.

		Predicted classes					
		0	1	2	Total	FN	Overall FN
Actual	0	225	2	44	337	46	163
	1	58	8	3	12	61	
	2	54	2	110	157	56	
	Total	271	69	166	506		
	FP	112	4	47			
	Overall TP	343					
	Overall FP	163					

Tab. A.5. Confusion Matrix for Environmental risk0.

		Predicted classes					
		0	1	2	Total	FN	Overall FN
Actual	0	282	52	146	480	198	217
	1	0	0	0	0	0	
	2	12	7	7	26	19	
	Total	294	59	153	506		
	FP	12	59	146			
	Overall TP	289					
	Overall FP	217					

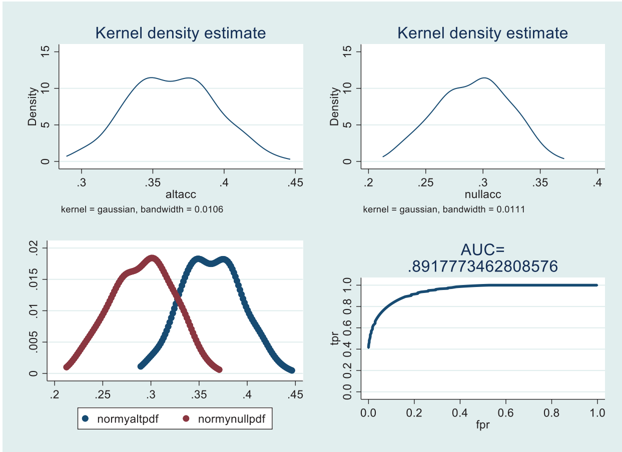
Fig. A.1. Roc curve for consumption model.



the consumption model and 57.9% with an ER of 42%. Results of the ACC, which is the probability of performing a correct classification, show a high probability for the consumption model.

To investigate the quality of the prediction in terms of sensitivity and specificity, the area under the receiver operating characteristic (ROC) curve (AUC) is also examined. Figure 4 shows the smoothed probability distributions for 100 alternative and null accuracy values by using the kernel density estimation (KDE, Gaussian kernel). The false positive rate (FPR), true positive rate (TPR), and area under the curve (AUC) come from the smooth pdfs derived from KDE (Peterson, 2010). The performance of the proposed model for consumption shows a high prediction at 92.82% in comparison to the environment, which is equal to 89.17% (Fig. 7 and 8).

Fig. A.2. Roc curve for the environment model.



Complementary material: Questionnaire

Questionnaire on the knowledge of genetic improvement techniques and attitude to consumption.

Section 1: Generalities

1) Gender
2) Age
3) Study field
4) Bachelor or master

Section 2: Attitude and risk perception about genetically modified crops

1) Do you agree with the following statement: Is food that contains ingredients obtained from genetically modified plants "safe to eat"?
   - I totally disagree
   - I disagree
   - I do not know
   - I agree
   - I completely agree
2) How would you rate the previous answer?
   - I'm not sure at all

- I'm pretty sure
- I'm absolutely sure

3) Do genetically modified crops represent a potential danger to the environment?
   - I totally disagree
   - I disagree
   - I do not know
   - I agree
   - I completely agree
4) How would you rate the previous answer?
   - I'm not sure at all
   - I'm pretty sure
   - I'm absolutely sure
5) Would you buy an apple that has not been chemically treated and in which pest resistance has been achieved through the use of biotechnology?
   - Yes
   - Only if the price is at least 10% lower than the conventional product
   - Only if the price is significantly lower than the conventional product
   - Never, under any circumstances
   - I do not know
6) How would you rate the previous answer?
   - I'm not sure at all
   - I'm pretty sure
   - I'm absolutely sure

Self-assessment of knowledge of techniques for genetic improvement of agricultural products.

7) How do you evaluate your knowledge on genetic breeding techniques?
   - 1 to 4
8) Of which techniques are you aware? (Multiple choice)
   - Crossing and selection
   - Mutagenesis
   - Assisted selection with molecular markers
   - In vitro culture techniques
   - Genome editing
   - Cisgenesis
   - Transgenesis
   - Others:
9) Which is your main information source on biotechnologies? (Multiple choice)
   - Press
   - Scientific articles
   - Television
   - Social media
   - Friends
   - None
   - Other:

Section 3: Objective knowledge evaluation

10) Is it possible to cultivate GMOs in Italy?
    - Yes
    - No
    - Yes, for not in-field experimentation
    - Yes, in field only for experimental use
    - I don't know
11) Is it possible in Italy to use animal feed containing components derived from genetically modified plants?
    - Yes
    - No
    - I don't know
12) What percentage of world maize production comes from genetically modified seed?
    > 0 – < 25%; > 25% – < 50%; > 50% – < 75%; > 75%
13) What percentage of world tomato production comes from genetically modified seeds?
    > 0 – < 25%; > 25% – < 50%; > 50% – < 75%; > 75%
14) What percentage of world wheat production comes from genetically modified seed?
    > 0 – < 25%; > 25% – < 50%; > 50% – < 75%; > 75%
15) What percentage of world soybean production comes from genetically modified seed?
    > 0 – < 25%; > 25% – < 50%; > 50% – < 75%; > 75%
16) What are the reasons that led to genetically modifying crops (multiple choice) * Check all that apply.
    - Insect resistance
    - Plant disease resistance
    - Resistance to herbicides
    - Improve the nutritional content
    - Reduce food waste
    - Reduce production costs
    - Reduce the use of fertilizers
    - Improvement of traceability
    - Promote adaptation to climate change. Safeguard biodiversity
    - Obtain varieties with superior quality characteristics
    - Other
17) Are the following statements true or false?
    - Non-GM tomatoes do not contain genes while genetically modified ones do
    - Maize always contained the same genes before it was possible to genetically modify it
    - All fresh vegetables contain deoxyribonucleic acid (DNA)
    - Brewer's yeast contains living organisms
18) Is it mandatory (according to Italian law) to indicate the presence of GM raw materials on food labels?
    - Yes
    - No

- Above a certain threshold
- I don't know

Section 4: Governance

19) Who, in your opinion, should make decisions about the possibility of producing genetically modified crops?
    - The Region
    - The State
    - The European Union
    - I don't know
20) Who, in your opinion, should make decisions regarding the labelling of genetically modified products?
    - The Region
    - The State
    - The European Union
    - I don't know
19) Decisions regarding the cultivation and labelling of GM products should be made predominantly on the basis of the opinion of:
    - Scientific experts
    - Popular consultation
    - I don't know

We proposed a short video (available upon request)

Section 5: repeated questions

20) Do you agree with the following statement: "Are foods that contain ingredients obtained from genetically modified plants "safe to eat"?
    - I totally disagree
    - I disagree
    - I do not know
    - I agree
    - I completely agree
21) How would you rate the previous answer?
    - I'm not sure at all
    - I'm pretty sure
    - I'm absolutely sure
22) Are genetically modified crops a danger to the environment?
    - I totally disagree
    - I disagree
    - I do not know
    - I agree
    - I completely agree
23) How would you rate the previous answer?
    - I'm not sure at all
    - I'm pretty sure
    - I'm absolutely sure
25) Would you buy an apple that has not been chemically treated and in which pest resistance has been achieved through the use of biotechnology?
    - Yes
    - Only if the price is at least 10% lower than the conventional product
    - Only if the price is significantly lower than the conventional product
    - Never, under any circumstances
    - I do not know
26) How would you rate the previous answer?
    - I'm not sure at all
    - I'm pretty sure
    - I'm absolutely sure