# Consumer's attitude in driving choices towards wine products derived from New Genomic Techniques (NGTs)

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## Abstract

New Genomic Techniques (NGTs) present an opportunity to enhance plant resistance to parasites or diseases, reducing dependence on agrochemicals, and to extreme climatic events such as heavy rainfall or long periods of drought, thus fostering better adaptation to climate change. However, the diffusion of these techniques may encounter obstacles deriving from the reluctance of farmers, who have to sustain costs in the introduction of new technologies whose production results are still uncertain, but also the resistance of the market, given the still widespread reluctance of consumers in accepting wine products derived from the use of these technologies.

Using original survey data from 1,045 respondents, we examine Italian consumers' acceptance of and decision to buy NGT wine products. To achieve this, we developed two indicators to assess the quality of the information and the respondents' level of knowledge about NGTs, our topic of interest. These indices were incorporated into a regression model to analyse their effects on the propensity to buy NGT wine alongside the socio-economic characteristics of respondents, which were categorized through cluster analysis.

Our findings suggest a reduction in Italian consumers' distrust toward these new technologies, possibly influenced by the European institutions' proposed regulatory revision.

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Additionally, the results indicate that the quality of information plays a crucial role in the decision to purchase NGT wine. This highlights the need for higher-quality information to empower consumers, helping them reach an adequate level of knowledge that would allow them to make better-informed choices.

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## Introduction

Modern society is facing major challenges in food production. On the one hand, extreme climatic events and rising temperatures in some areas are making the cultivation of traditional crops more difficult. On the other hand, excessive use of pesticides and fertilisers presents serious hazards to both human health and the environment. These challenges are extremely significant in wine production, where climate change has negatively impacted grape yield and quality (Marín *et al.*, 2021). Additionally, wine grapes are among the processed food samples with the highest frequency of multiple pesticide residues according to the latest report on pesticide residues in food published by the European Food Safety Authority (EFSA, 2023). Despite the increasing demand for more sustainable viticulture, individual and wine characteristics create a complex framework for decision-making. In this context, New Genomic Techniques (NGTs) present an opportunity to apply scientific progress in viticulture.

NGTs encompass a diverse group of techniques, many of which enable genome corrections without the need for DNA manipulations or altering the plant's genetic heritage in addressing wine production challenges, NGTs can enhance plant resistance to parasites or diseases, reducing dependence on agrochemicals, and extreme climatic events such as heavy rainfall or long periods of drought, thus fostering better adaptation to climate change. For these reasons, NGT products have the potential to make agri-food systems more resilient and sustainable, contributing to the innovation and sustainability objectives of the European Green Deal and Farm to Fork Strategy (European Commission, 2021).

Since 2001, the Directive 2001/18/EC has established the regulatory framework for the authorisation, supervision, and labelling of Genetically Modified Organisms (GMOs) and GM products within the European Union (EU). However, recent advancements in genome engineering have prompted a revision of the Union law. The authorisation procedures and assessment requirements for GMOs are considered disproportionate or inadequate for plants produced using these new techniques. In July 2023, the European Commission proposed a New Regulation on plants produced by certain NGTs

(COM(2023) 411 final), which was later approved by the European Parliament on 7 February 2024. The proposal suggests the exemption from regulations on GMOs of Category 1 NGT plants, defined as plants that contain genetic material from the same plant, while transgenic plants will remain subject to the GMO legislation as it stands today.

Beyond regulatory challenges, public perception is a key factor for the commercialisation of food products derived from NGTs. Reluctance toward GM products has historically shaped public opinion and has significantly hindered their development and commercialization (McFadden, 2016; Voigt & Münichsdorfer, 2019). Especially in Europe, where consumers show a clear preference for organic products – widely perceived as more 'natural' – GM products tend to be approached with greater caution (Wolf *et al.*, 2012). Scholars are actively working to understand the factors influencing consumers' food choices, including perceptions and consumption patterns (Strobbe S. *et al.*, 2023; Romeo Lironcurti S. *et al.*, 2024; Kim, J. and Fang, S. 2020). The existing literature shows how consumers remain sceptical and reluctant when making food choices, leaving uncertainties about how these choices are made and what they consider to be healthy food (Funk and Kennedy, 2016).

Particular attention should be directed to the trade-off between objective and subjective knowledge, that is, between what consumers believe they know and what they do know. The literature has also addressed the impact of this imbalance on consumer attitudes, particularly in evaluating the risks and benefits associated with genetic modification (Hwang & Nam, 2021). Consumers, despite having limited objective knowledge, may believe they know enough, and conversely, even with a high level of objective knowledge, they may perceive their subjective knowledge as low. Measuring these two types of knowledge separately can clarify which one has a more significant influence on consumer choices, providing insights for effectively communicating the benefits associated with them, thereby promoting the potential for a future market for these products (Lusk *et al.*, 2018).

The role of information in consumers' acceptance of GM foods is still a topic of debate in the literature. Some scholars strongly argue that promoting the benefits of GM foods for environmental sustainability and food safety may increase acceptance (Beghin & Gustafson, 2021; Lusk *et al.*, 2004; Wunderlich, 2019), while others believe that the role of information is not as significant (Wuepper *et al.*, 2018). Anyway, the flow of information from various sources is crucial to building consumer knowledge. Scholars have observed that the primary sources of GMO knowledge for consumers are Internet sources (77,3%), which are often used as the main method of communication to transfer information (Wunderlich & Gatto, 2015; Demaria *et al.*, 2024; Romeo Lironcurti *et al.*, 2024). Hence, it is crucial to

consider the flow of information and the sources from which it originates in order to understand the quality of the information users receive and, consequently, their actual level of knowledge on the topic. Consumer attitudes are influenced by the source of innovation, with lower confidence when it originates from private companies (Lemarie, Marette, 2022; Lusk *et al.*, 2018). Acceptance tends to be higher when consumers are fully informed about the NGT innovation process, which supports the potential for NGT food market growth.

The economic analysis of the propensity to buy NGT-derived products relies on experimental surveys, as these products are not yet available on the market and aligns with previous studies on consumer behaviour towards GMO-derived foods.

This research contributes to the limited body of literature on consumer behaviour regarding NGT wine products, which has primarily focused on fungus-resistant grapes (Borello *et al.*, 2021; Vecchio *et al.*, 2022; Pretorius and HØJ, 2008), offering insights into how consumer knowledge and information can shape the acceptance of new agricultural technologies. Understanding these factors is crucial for promoting the market for NGT-based wines and aligning consumer attitudes with the potential benefits of these innovations. To add some evidence to the empirical literature, our study is focused on the following two research questions:

**RQ1**: *What is the role of information in building consumers' opinion on NGTs and how this influences their decision to buy NGT wine products?*

**RQ2**: *Measure the difference between respondents' subjective and objective knowledge on NGTs and investigate whether and how it drives consumer's choices.*

Our study is based on an original survey and investigates how the knowledge and perceptions of Italian consumers regarding NGTs influence their decision to purchase wine produced using these innovative methods.

Using cluster analysis, we created homogeneous groups of individuals based on their socio-economic characteristics. We also developed two indicators to assess the quality of the information and the respondents' level of knowledge regarding the topics discussed. Finally, we used the clusters and the indices in a regression model to examine their effects on the propensity to buy NGT wines.

In the following section of the article, we illustrate more in detail the methodology; in the last section we discuss the results and finally we draw our conclusions and suggest some policy recommendations.

## 2. Methodology and data

### 2.1. *Data collection*

For the analysis, we used data collected from an original survey conducted by the Appinio research agency, located in Germany, in April 2024, on a sample of 1,045 Italian consumers aged 18 and above, located in Italy. The survey was administered using computer-assisted web interviewing (CAWI) where participants were selected via simple random methodology. To ensure that the sample was representative of the Italian population in terms of gender, age, and origin – and to allow for inferences about the overall population – the collected distribution was compared with the ISTAT census data from January 2024. No significant deviations were found, confirming that the sample reflects the broader Italian population rather than a specific geographic location. Appinio's quality controls ensured a high standard of response reliability, with a margin of error of approximately 4.38% at the 95% confidence level.

### 2.2. *Survey design*

The survey includes 30 questions, four sections, and a segment dedicated to personal inquiries.

The first section of the survey includes ten questions on the Italian people's wine consumption habits, such as regularity of consumption, consumption places, and attributes in wine choice.

The second section evaluates participants' subjective and objective knowledge levels regarding NGTs, as well as perceptions of food and environmental safety, through a set of eight questions.

The third section explores consumers' propensity to buy (PTB) and willingness to pay for wine derived from genetic modification.

The fourth section investigates the informational tools Italian consumers rely on to build their knowledge on these topics. Finally, the survey is completed by administering personal questions about income, education, and marital status as shown in Table 1.

*Table 1 - Demographic characteristics of the sample (participants N. 1,045)*

|  |  | (%) |
|---|---|---|
| **Gender** | Male | (49.6) |
|  | Female | (50.4) |
| **Income** | €0-€10,000 | (15.9) |
|  | €10,000-€20,000 | (25.8) |
|  | €20,000-€25,000 | (18.9) |
|  | €25,000-€30,000 | (13.2) |
|  | €30,000-€40,000 | (14.8) |
|  | €40,000+ | (11.4) |
| **Education** | PhD in other | (3.3) |
|  | PhD in agricultural sciences / chemistry / biology / medicine | (3.1) |
|  | Degree in other | (28.6) |
|  | Degree in agricultural sciences / chemistry / biology / medicine | (5.6) |
|  | High school diploma | (49.6) |
|  | Middle school diploma | (9.9) |
| **Household** | Married (or cohabiting) without children | (18.0) |
|  | Married (or cohabiting) with one child | (21.5) |
|  | Married (or cohabiting) with two or more children | (24.2) |
|  | Single | (33.3) |
|  | None of the above | (3.0) |

*Source*: Own elaboration on survey data.

For the study presented in this article, we focused on specific parts of the questionnaire, particularly on questions from sections two and three. The selected questions for analysis address: (1) the PTB wine derived from NGTs; (2) the respondents' subjective and objective knowledge of NGTs; and (3) the information tools used by Italian consumers, along with the quality and frequency of their use. Additionally, we considered the main socio-demographic characteristics of the respondents. Below are the details of the questions used to construct variables for the analysis.

*Table 2 - Survey questions for variable construction*

| PTB (Dependent variable) | Assessment of the propensity to purchase wine derived from NGTs |
|---|---|
| Would you buy a wine that comes from new genetic modification techniques (NGTs)? | 1=Not; 2=Probably not; 3=I don't know; 4=Probably yes; 5= es |
| **Knowledge** | **Questions to evaluate the subjective and objective consumers' knowledge** |
| How would you assess your knowledge of new genetic modification techniques in agriculture (NGTs)? | (from 1=no knowledge to 5=excellent knowledge) |
| Are you familiar with or have you heard of Mutagenesis? | yes / no |
| Are you familiar with or have you heard of Transgenesis? | yes / no |
| Are you familiar with or have you heard of Cisgenesis? | yes / no |
| Are you familiar with or have you heard of Genome editing? | yes / no |
| Are you familiar with or have you heard of Crossbreeding and Selection? | yes / no |
| A: The new genetic modification techniques use genome editing technology | 1=true; 2=false; 3=I don't know |
| B: The new genetic modification techniques exclusively use the genetic material of the plants themselves | 1=true; 2=false; 3=I don't know |
| C: The new genetic modification techniques insert genes from another organism, modifying specific parts of the genes in the recipient plant | 1=true ; 2=false ; 3=I don't know |
| D: The new genetic modification techniques involve a true genetic manipulation of the DNA | 1=true; 2=false; 3=I don't know |
| E: The new genetic modification techniques do not use the genetic material of the plants themselves but partially insert DNA from other organisms | 1=true; 2=false; 3=I don't know |
| F: I am not familiar with any of the mentioned techniques (not randomized) | X |

| Acceptance and perceived benefit | Questions to assess the acceptability of the risks associated with these technologies |
|---|---|
| In your opinion, are food products derived from NGTs safe for consumption? | 1=Not; 2=Probably not; 3=I don't know; 4=Probably yes; 5=Yes |
| In your opinion, NGTs are safe for the environment? | 1=Not; 2=Probably not; 3=I don't know; 4=Probably yes; 5=Yes |
| Do you believe that products derived from NGTs can have better nutritional values compared to conventional products? | 1=Not; 2=Probably not; 3=I don't know; 4=Probably yes; 5=Yes |
| **Information tools** | **Questions to assess the acceptability of the risks associated with these technologies** |
| Have you heard about NGTs through 'scientific journals'? | yes / no |
| Have you heard about NGTs through 'podcast'? | yes / no |
| Have you heard about NGTs through 'newspapers/magazines'? | yes / no |
| Have you heard about NGTs through 'tv/ radio'? | yes / no |
| Have you heard about NGTs through 'internet/social media'? | yes / no |
| Have you heard about NGTs through 'Friends and acquaintances'? | yes / no |
| None, I have never heard of it (not randomized) | X |
| **Other information tools** | **Open-ended response** |
| How often have you heard about NGTs in 'scientific journals'? | 1=Once or more a week; 2=Once or more a month; 3=Once or more every 3 months; 4=Once or more every 6 months; 5=Less frequently |
| How often have you heard about NGTs on 'podcast''? | 1=Once or more a week; 2=Once or more a month; 3=Once or more every 3 months; 4=Once or more every 6 months; 5=Less frequently |
| How often have you heard about NGTs in 'newspapers/magazines'? | 1=Once or more a week; 2=Once or more a month; 3=Once or more every 3 months; 4=Once or more every 6 months; 5=Less frequently |

| How often have you heard about NGTs on 'tv/radio'? | 1=Once or more a week; 2=Once or more a month; 3=Once or more every 3 months; 4=Once or more every 6 months; 5=Less frequently |
|---|---|
| How often have you heard about NGTs on the internet/social media? | 1=Once or more a week; 2=Once or more a month; 3=Once or more every 3 months; 4=Once or more every 6 months; 5=Less frequently |
| How often have you heard about NGTs from friends and acquaintances? | 1=Once or more a week; 2=Once or more a month; 3=Once or more every 3 months; 4=Once or more every 6 months; 5=Less frequently |
| Do you believe that information channels guide your choices correctly regarding food products derived from new genetic modification techniques (NGTs)? | 1=Not; 2=Probably not; 3=I don't know; 4=Probably yes; 5= es |

*Source*: Own elaboration on survey data.

### 2.3. *Methodology*

To answer the first research question, we built an index to summarize and standardize survey responses related to the quality and media used to obtain information on NGTs, including perceptions of the accuracy of the information. To achieve this, we identified the information channel with the highest quality level used by each respondent, and we then multiplied it by its maximum frequency of individual use. The quality of the information channels was assessed by assigning each tool a level of scientific information, ranging from the lowest (e.g., internet and friends) to the highest (scientific journals), as outlined in Table 3.

*Table 3 - Variables for information quality index construction*

| **Max_quality** | *Quality of information channels* | Index=0 (none); index=1 (internet & friends); index=2 (Newspapers and TV; index=3 (scientific journal & podcast) |
|---|---|---|
| **Freq_info** | *Total frequency of information channels* | Index capturing the max frequency value of using information channels |

*Source*: Own elaboration on survey data.

We then normalise it as in the following formula:

$$Info\_quality\_ratio_i = \frac{max\_quality_i * freq\_max\_quality_i}{max\,(quality * freq)} \tag{1}$$

Where $max\_quality_i$ is the highest level of quality of the information channel used by *ith* respondent; $freq\_max\_quality_i$ is the maximum frequency of the highest quality channel used by *ith* respondent in one year. The index ranges between 0 and 1, where 1 is the highest level of quality information.

Concerning the second research question, we aim to determine whether consumers accurately estimate their knowledge of NGTs or they tend to overestimate/underestimate it – that is, whether the reported level of knowledge corresponds to actual knowledge of these technologies. To do so, we compared their self-reported perceptions of their knowledge level (subjective knowledge) with their actual knowledge level on NGTs (objective knowledge). The latter is assessed through several questions regarding the main characteristics of different GM technologies. If respondents' answers about their subjective knowledge do not align with those assessing their objective knowledge, it suggests that they may either overestimate or underestimate their knowledge. Table 4 illustrates the matrix used to define the values of the index.

*Table 4 - Consumer's confidence matrix*

| | | SUBJECTIVE KNOWLEDGE | |
| --- | --- | --- | --- |
| | *0 (None)* | *1 (Decent)* | *2 (Excellent)* |
| **0 (None)** | *Accurate estimation* | Overestimation | Overestimation |
| **1 (Decent)** | Underestimation | *Accurate estimation* | Overestimation |
| **2 (Excellent)** | Underestimation | Underestimation | *Accurate estimation* |

*(left axis label: OBJECTIVE KNOWLEDGE)*

*Source*: Own elaboration on survey data.

To evaluate whether and to what extent these two indices help consumers to make informed choices of purchasing and can push the consumer to buy or not buy wine derived from NTG, we estimated respondents' propensity to buy NGT wine products. We codified the PTB variable in five categories.

The variable assumes value 1 if they would not buy NGTs wine products, 2 if they answered that they would probably not buy them, 3 if they are uncertain about buying NTG products or not, 4 if they would probably buy them and finally 5 if they would buy NGT wine products. This variable was used as ordinal, ranging from 1 to 5, with the values ranked in hierarchical order.

Using the PTB as the dependent variable, we regressed the two indices, which were included as explanatory variables. Additionally, we included a control variable representing homogeneous consumer groups, to account for respondents' personal characteristics. This approach allowed us to isolate the effect of these characteristics on purchasing decisions, ensuring that our estimates for the two key variables of interest – the quality of information and knowledge of technologies – remained unbiased.

More in detail, several socioeconomic variables were used to identify groups of respondents that are internally homogeneous but differ from one another based on these characteristics. This classification was achieved through a cluster analysis.

Two key considerations motivated this additional methodological step. First, it was necessary to account for interactions and correlations among the variables used in the regression, such as age, education, and income levels. Second, this approach provided additional information by identifying a summary profile of the "typical" consumer, who may have a greater or lesser propensity to purchase NGT products.

We conducted a cluster analysis using the K-median method in STATA software to identify homogeneous groups based on respondents' socio-economic profiles.

K-medians clustering in STATA is an iterative procedure that partitions the data into *k* groups or clusters, based on the homogeneity of individuals' characteristics. The procedure begins with *k* initial group centers, and observations are assigned to the group with the nearest center. The median of the observations assigned to each of the groups is calculated, and the assignment process is repeated. These steps continue until all observations remain in the same group as in the previous iteration.

Once each individual was assigned to a group, we calculated the descriptive statistics of the socioeconomic variables for each group. This allowed us to define the average profiles associated with the consumer groups.

Through this procedure, we obtained a categorical variable, where each occurrence represents a distinct 'profile' of consumers identified through the cluster analysis. As it will be shown in detail in the results section, four consumer groups with specific socioeconomic profiles were identified based on the cluster analysis applied to our data.

This categorical variable was finally included as an explanatory variable in the regression to estimate how the different socioeconomic profiles of the respondents influence their decision to buy or not to buy NGT wine products. Formally the regression equation is the follows.

$$PTB_i = \beta_{1,i} + \beta_{2,i}IQI_i + \beta_{3,i}CKI_i + \beta_{4,i}\delta_i^{profile1} + \beta_{5,i}\delta_i^{profile2} \ldots + \beta_{6,i}\delta_i^{profile\ n-1}$$

Where:

$PTB_i$ is the ordinal variable representing the purchase choices of the *ith* consumer, which ranks in hierarchical order from "surely not purchase" to "surely purchase";

$IQI_i$ is the level of information quality index, associated to the *ith* consumer;

$CKI_i$ is the index of NTGs' knowledge index of the *ith* consumer;

The $\delta_i^{profile1}$ ... $\delta_i^{profile1}$ are variables representing the socioeconomic profiles of consumers. These are derived from our categorical variable indicating homogeneous groups of respondents, which was recoded with N levels into N-1 indicator variables $\delta_i^{profilej}$, which gives the value 1 if observation I is in category profile j and zero otherwise.

Finally, the $\beta_{1,i} \ldots \beta_{n,i}$ stand for the unknown model parameters that we are trying to estimate, they estimate the mean differences in Y for one unit change in the predictor $X_i$.

Table 5 illustrates all the variables used in the analysis.

*Table 5 - Variables description*

| Name | Description | Values |
|---|---|---|
| **PTB** | Choice to buy NGT wine products or not | 1="Not"; 2="Probably not"; 3="I don't know"; 4="Probably yes"; 5="Yes" |
| **Info_quality_ratio** | Synthetic index combining quality and frequency of information channels | Index ranging from 0 (none) to 1 (max) |
| **Cons_confidence** | Index combining consumer's objective and subjective knowledge to estimate their confidence on the subject | Index assuming value 1 (underestimation), 2 (accurate estimation), 3 (overestimation) |
| **Age** | Consumers' age | Age ranging from 18 to 65 |
| **Income** | Consumers income level | 1<10,000€; 2=10,000€-20,000€; 3=20,000€-25,000€; 4=25,000€-30,000€; 5=30,000€-40,000€ 6>40,000€ |

| Name | Description | Values |
|---|---|---|
| **Education** | Educational level | 1=Middle school; 2=Diploma; 3=Bachelor/Master/PhD; 4=Bachelor/Master/PhD in medicine, biology, chemistry and agrarian |
| **Gender** | Consumer's gender | Dummy variable=1 if female |

*Source*: Own elaboration on survey data.

## 3. Results

In this section, we report some descriptive statistics on the variables used and the results of the regression analysis.

### 3.1. *Key Drivers of Consumer Purchase Behaviour*

We first focus on the PTB of NGT wine products. Even if most of the literature showed that consumers are still sceptical about genetically modified food (Wolf *et al*., 2012), based on our survey's responses, it is evident that consumers are willing to purchase wine produced from NGTs. More specifically, 59.4% of respondents answered that they would surely or probably buy it; whereas 21.2% replied that they do not know and 19.4% replied that they would not and probably not buy it.

Given the role of information and knowledge in shaping consumers' acceptance of the products, we deepened the analysis of the two indices (1) and (2) to evaluate their impact on the PTB of our sample. Since almost 60% seem to be open to the idea of buying NGT wine products, we expect, on average, a high-quality level of information and accuracy of participants' knowledge on the topic.

Before analysing the role of information and of knowledge on consumer choices, we also observe the average socio-economic and personal profile of respondents to try to explain this result.

Our sample is representative of the Italian population of over 18 years old as it was collected according to the ISTAT census, as specified in the previous section, with the average age of respondents is 42 years old. As reported in Table 1, our sample is composed of 50.4% of women and earns on average between €20,000 and €25,000. Additionally, our sample has an average level of education of a high school diploma and a high percentage (more than 40%) of the sample has the highest educational level

(bachelor/master/PhD). More than 45% of the sample is married with one or more children, while 33% is single (Table 1). Figure 1, that illustrates the distribution of age of respondents grouped according to different levels of PTB, shows that the median age of purchasing groups decreases as the PTB increases indicating that young consumers seem to be more prone to purchase NGT wine products.

*Figure 1 - PTB and consumer's age*
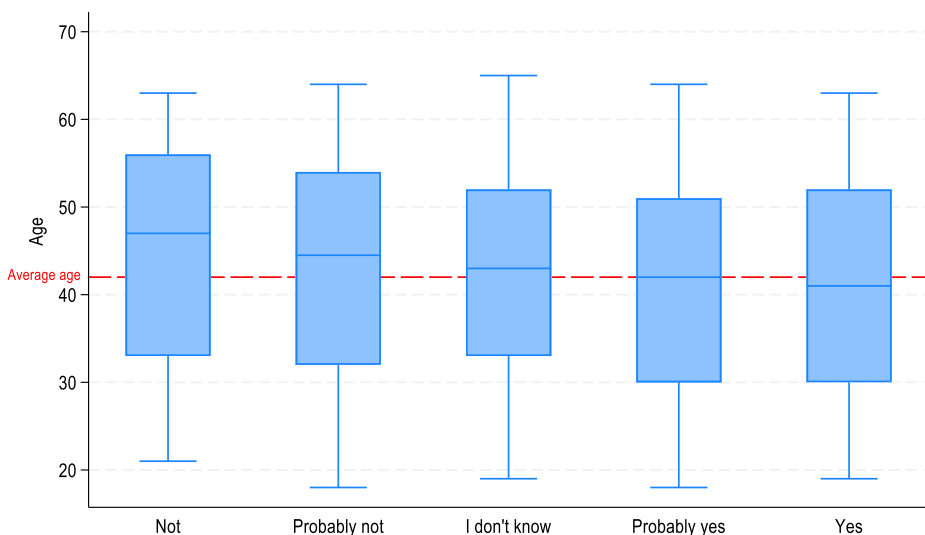


*Note*: The box plots have a distribution range going from the lower adjacent value (5th percentile) to the upper adjacent value (95th percentile), with the box ranging from the lower hinge (25th percentile) to the upper hinge (75th percentile).
*Source*: Own elaboration on survey data.

Table 6 illustrates that the percentage of consumers with the highest levels of education (bachelor/master degree/PhD) increases when closer to the decision to buy NGT wine products.

When analysing consumption choices depending on the income classes, it emerges that higher income levels tend to increase the decision of consumers to buy NGT wine products, compared to lower income levels (Figure 2).

Findings suggest that higher levels of education, lower age and higher levels of income move consumers towards the decision to buy NGT wine products.

*Table 6 - Consumer's educational level and PTB*

| Education | dip_PTB_5 | | | | | Total |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| 1 | 11.11 | 9.29 | 13.06 | 8.67 | 8.82 | 9.86 |
| 2 | 53.97 | 56.43 | 49.10 | 48.67 | 45.29 | 49.57 |
| 3 | 28.57 | 27.14 | 30.18 | 33.78 | 34.12 | 31.87 |
| 4 | 6.35 | 7.14 | 7.66 | 8.89 | 11.76 | 8.71 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

*Source*: Own elaboration on survey data.

*Figure 2 - PTB and consumer's income*
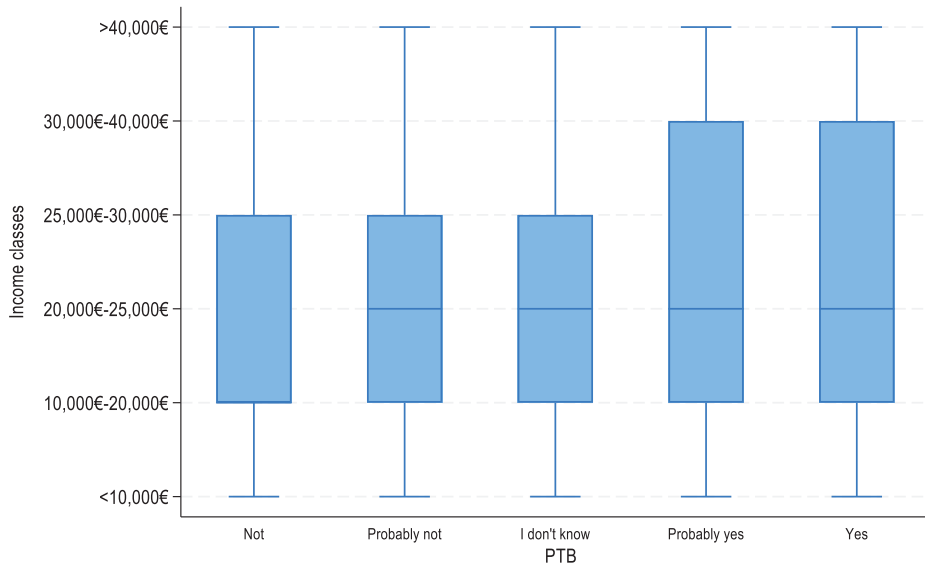


*Note*: The box plots have a distribution range going the lower adjacent value (5th percentile) to the upper adjacent value (95th percentile), with the box ranging from the lower hinge (25th percentile) to the upper hinge (75th percentile).
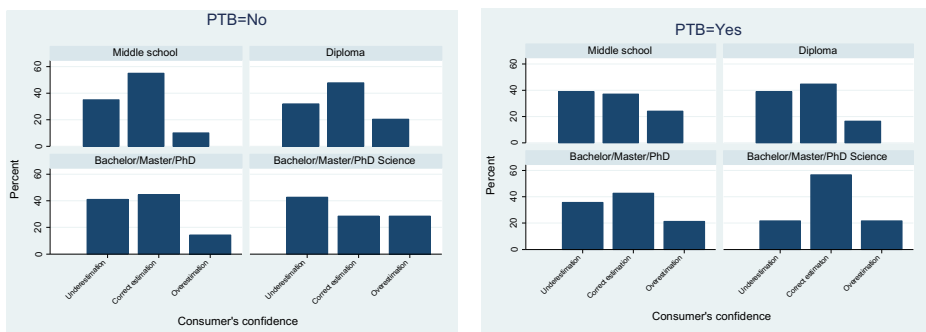*Source*: Own elaboration on survey data.

Concerning consumer knowledge, the descriptive analysis reveals that many respondents claim to have a good or even excellent knowledge of genetic improvement in agriculture (respectively, 51,3% and 5% of the answers. This result is only partially consistent with Wunderlich and Gatto (2015), who highlight that consumer knowledge and awareness of

GM products are limited, with only 28.0% of Italian consumers expressing familiarity with them. However, our findings are supported by correct responses in the section where the understanding of key GM techniques was assessed (objective knowledge). In other words, we examine the discrepancy between actual knowledge and perceived knowledge, as an imbalance between the two may affect decision-making (Hwang and Nam, 2021). However, respondents claimed that traditional genetic improvement techniques were better than modern ones, such as cisgenesis, and genome editing. While only 27.1% of respondents do not know any of the proposed genetic modification techniques. A solid understanding of the subject is associated with a certain degree of positivity regarding the use and consumption of these products.

Overall, consumers tend to accurately estimate their knowledge about NGTs. However, there is an interesting difference between consumers who would buy NGT wine and those who would not. This difference is particularly noticeable among individuals with a middle school education and those with higher education in scientific fields. Our results show that for individuals with low levels of education, the decision not to purchase is not due to distorted knowledge (overestimation). Moreover, a clear bias emerges among individuals with higher levels of education, particularly in scientific fields (Figure 3).

*Figure 3 - Consumer's confidence, PTB and educational levels*



*Note*: In this graph "PTB = No" aggregates consumers that replied that they would "Not" and "Probably not" buy NGT wine products, and "PTB = Yes" aggregates consumers that replied "Yes" and "Probably yes" to the same question.
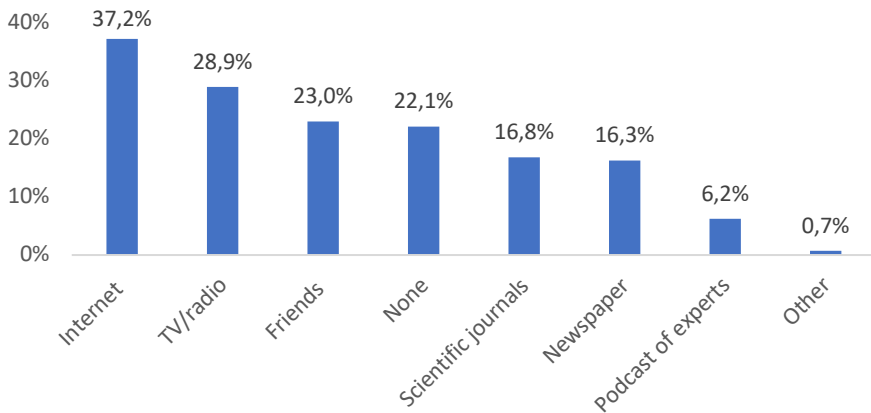*Source*: Own elaboration on survey data.

Regarding information sources, Figure 4 shows the channels that Italian consumers most commonly use to learn about NGTs. What emerges from the descriptive results is that more than 20% of respondents stated that

does not have any knowledge on the topic. In addition, findings show that a more accurate information is underutilized: 16.8% of respondents answered that they use scientific journals to get information on the topic, while the information retrieved from the internet and social media channels consistently yield the highest results (37.2%). This last result is in line with Sendhil *et al.* (2022) that identifies the Internet as the main information source used by consumers. Other channels used for sharing information are forums and podcasts of experts, that are used by 6.2% of respondents. Finally, television and radio also remain popular choices, with 28.9% of respondents mentioning them.

*Figure 4 - Information tools*



*Note*: Respondents were able to select multiple tools.
*Source*: Own elaboration on survey data.

As explained in the methodology section, we built a synthetic index that considers both the quality and frequency of the channels used by Italian consumers. Hence, we tested the relation between this index and the PTB, finding that the two variables are directly proportional (Figure 5). This indicates that the more accurate the information, the more likely consumers are to purchase NGT wine.
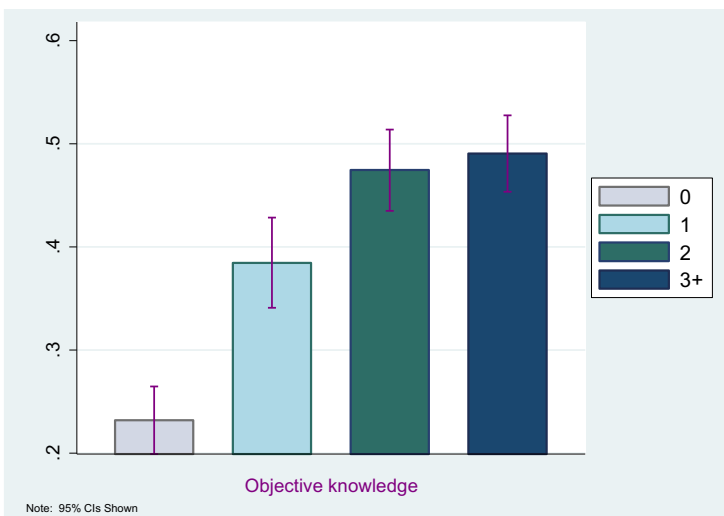
*Figure 5 - Information Quality Ratio and PTB*
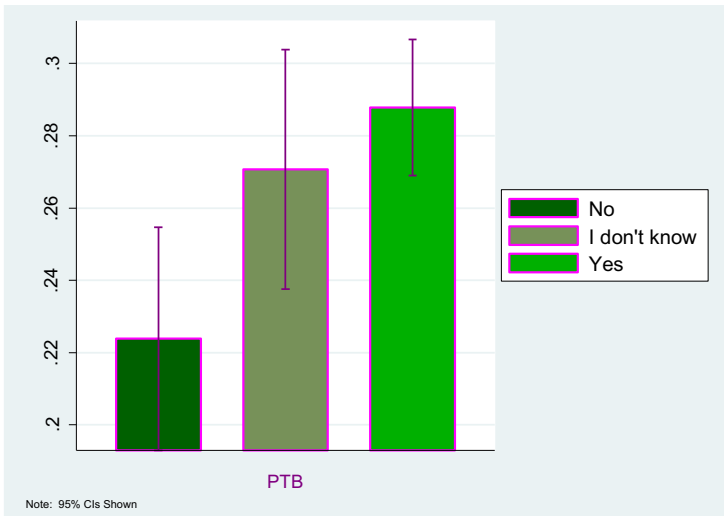


Source: Own elaboration on survey data.

Figure 6 shows that our synthetic information quality index is positively correlated with consumers' objective knowledge on the topic, aligning with our expectations.

*Figure 6 - Information Quality Ratio and consumer's objective knowledge on NGTs*



Source: Own elaboration on survey data.

As predicted, Figure 7 shows a positive relation between the quality of information and consumers' personal income. Additionally, we find that as personal income increases, the percentage of undecided consumers decreases, with more consumers placing themselves in either the "Yes" or "Not" group.

*Figure 7 - Income classes, Information Quality Ratio and PTB*
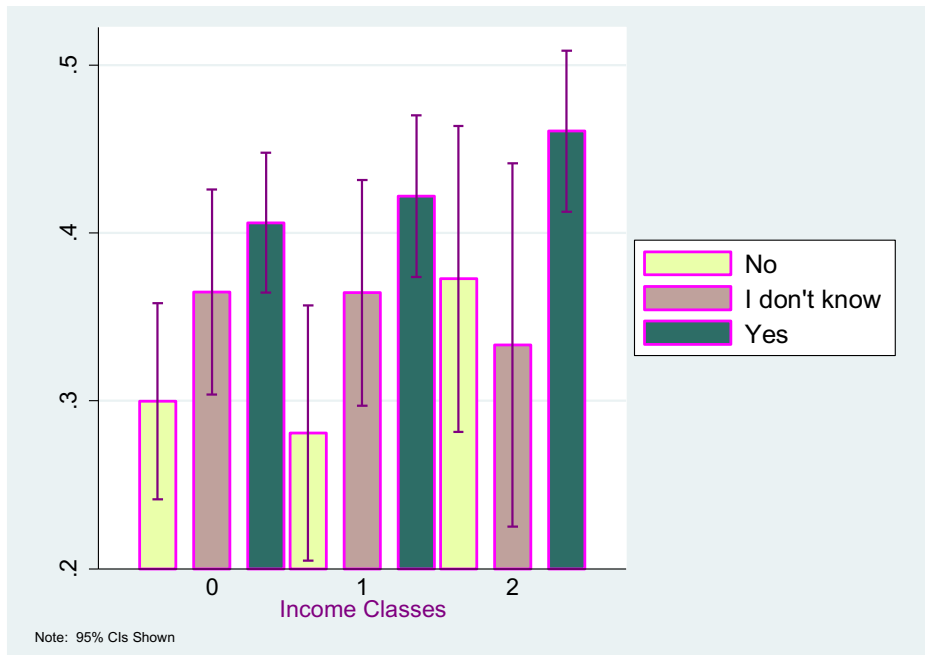


*Note*: We aggregated income classes in the following classes: 0 = <€20,000; 1 = €20,000-€30,000 and 2 = >€30,000. In this graph "PTB = No" aggregates consumers who replied that they would "Not" and "Probably not" buy NGT wine products, and "PTB = Yes" aggregates consumers who replied "Yes" and "Probably yes" to the same question.
*Source:* Own elaboration on survey data.

### 3.2. *Regression results*

As mentioned in the methodology, the study aims to analyse the role of information acquired and consumers' knowledge in shaping their propensity to purchase NGT products. To achieve this, we use a regression model, where PTB is the dependent variable, while the two indexes, representing the quality of information and the accuracy of consumers' knowledge of each individual, are included as independent variables. By examining the coefficients of these

variables, we tried to estimate the magnitude of the effects of such measures on the choice to purchase NTG products. Additionally, to account for the effects of personnel characteristics of respondents, we included, among the independents, a categorical variable, representing different socio-economic profiles of our sample. To identify homogeneous respondent groups (clusters) from a socio-economic perspective, we apply cluster analysis using the K-medians estimation method.

The K-means (or median) is an effective non-hierarchical clustering method, where partitions are created in such a way that non-overlapping groups have no hierarchical relationships with each other. This technique is relatively stable, offering greater reliability and speed compared to hierarchical clustering. Furthermore, it tends to perform better than hierarchical clustering in the presence of errors. However, unlike hierarchical methods, the resulting clusters can be more difficult to interpret and analyse.

The procedure requires the indication of the groups to be formed. After conducting several clustering trials, a Cluster-gram graph was drawn to examine how members are assigned to clusters as the number of clusters increases. This graph is particularly useful in exploratory analysis for non-hierarchical clustering algorithms, helping to determine the optimal number of clusters to form (Fig. 8).

*Figure 8 - Cluster-gram*
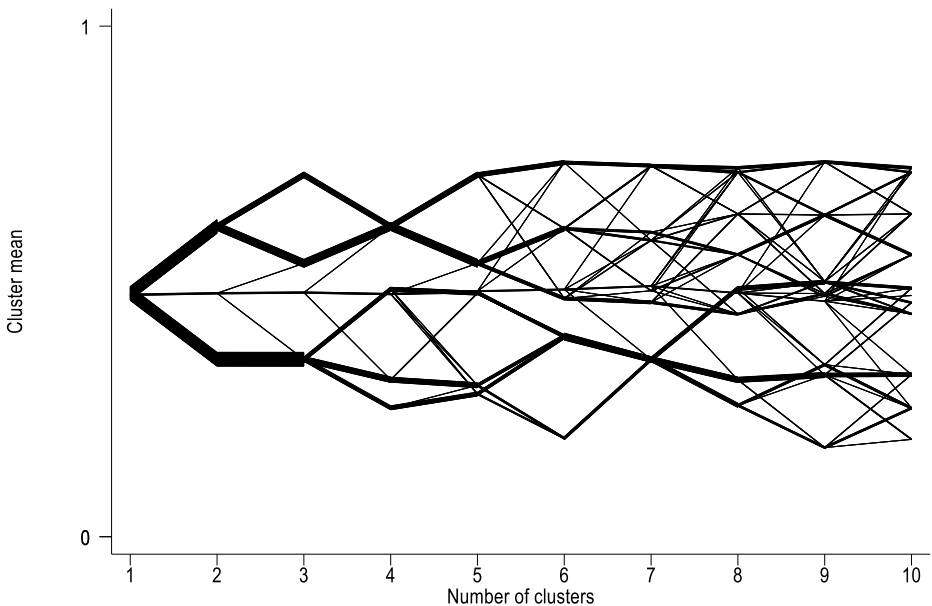


*Source*: Own elaboration on survey data.

We decided to cluster our respondents into six groups, ensuring homogeneity of groups based on the following variables: age, gender, income class and educational level. It is also important to note that for this clustering method to be applied correctly, all variables must have the same scale to prevent any single variable from exerting disproportionate influence. When features are at different scales, some algorithms may be biased towards features with wider ranges, potentially leading to suboptimal model performance.

To address this, we normalized the data to ensure that all variables were on the same scale, allowing all features to be treated equally and improving the model's ability to learn from data. We then applied the Min-Max normalization of our starting variables.

Table 7 shows key statistics for the variables used in clustering, allowing us to describe the median profile of each of the six identified groups.

*Table 7 - Statistics of socioeconomic characteristics of consumers groups*

| Cluster-ID | N | Median | Min | Max | SD |
|---|---|---|---|---|---|
| **1** | | | | | |
| Educational level | 141 | 2 | 1 | 4 | .7 |
| Income classes | 141 | 2 | 1 | 4 | .8 |
| Age (years) | 141 | 28 | 18 | 44 | 6.6 |
| Female (dummy) | 141 | 2 | 2 | 2 | 0 |
| **2** | | | | | |
| Educational level | 210 | 3 | 2 | 4 | .6 |
| Income classes | 210 | 3 | 1 | 6 | 1.5 |
| Age (years) | 210 | 32 | 18 | 58 | 9.6 |
| Female (dummy) | 210 | 1 | 1 | 1 | 0 |
| **3** | | | | | |
| Educational level | 120 | 2 | 1 | 3 | .5 |
| Income classes | 120 | 1 | 1 | 3 | .5 |
| Age (years) | 120 | 37 | 18 | 55 | 10.6 |
| Female (dummy) | 120 | 1 | 1 | 1 | 0 |
| **4** | | | | | |
| Educational level | 164 | 3 | 2 | 4 | .6 |
| Income classes | 164 | 5 | 2 | 6 | .9 |
| Age (years) | 164 | 40 | 21 | 64 | 10 |
| Female (dummy) | 164 | 2 | 2 | 2 | 0 |

| Cluster-ID | N | Median | Min | Max | SD |
|---|---|---|---|---|---|
| **5** | | | | | |
| Educational level | 213 | 2 | 1 | 4 | .6 |
| Income classes | 213 | 3 | 1 | 6 | 1.3 |
| Age (years) | 213 | 51 | 30 | 64 | 6.8 |
| Female (dummy) | 213 | 2 | 2 | 2 | 0 |
| **6** | | | | | |
| Educational level | 197 | 2 | 1 | 4 | .5 |
| Income classes | 197 | 3 | 1 | 6 | 1.5 |
| Age (years) | 197 | 55 | 38 | 65 | 5.9 |
| Female (dummy) | 197 | 1 | 1 | 1 | 0 |

*Source*: Own elaboration on survey data.

Based on Table 7 we can describe the main characteristics of each consumer group as follows:
1. **Group 1** (141 respondents) consists primarily of male respondents, around 28 years old, with a high school education and an annual income between 10,000 and 20,000 euros.
2. **Group 2** (210 respondents) is mainly characterized by the presence of 32-year-old women, holding a bachelor's degree or higher, with a yearly income of 20,000-25,000 euros.
3. **Group 3** (120 respondents) is mainly composed of females, approximately 37 years old, with a high school education and an income of less than 10,000 euros.
4. **Group 4** (164 respondents) differs significantly from the previous group, consisting primarily of men in their forties who are university graduates and with an annual income ranging between 30,000 and 40,000 euros.
5. **Group 5** (213 respondents) is mainly composed of men, with an average age of 51 and a high school education, and an income between 20,000 and 25,000 euros.
6. **Group 6** (197 respondents) consists mainly of women, who are on average 55 years old, with high school education and an annual income of approximately 20,000-25,000 euros.

Using PTB as a dependent variable, we performed a linear regression model, in which the two indices – representing the quality of information and consumer knowledge – as well as their socioeconomic profiles, were included as independent variables.

Table 8 shows the regression model results, while Figure 9 depicts the estimated margins for socioeconomic profile groups.

*Table 8 - Regression Results (Y = Propensity to buy)*

| Variables | Coefficients |
|---|---|
| Info Quality Ratio | 0.56*** |
| Cons_confidence 1 | −0.15* |
| Cons_confidence 2 | baseline |
| Cons_confidence 3 | −0.20** |
| Cluster 1 | baseline |
| Cluster 2 | 0.28** |
| Cluster 3 | 0.08 |
| Cluster 4 | 0.36*** |
| Cluster 5 | 0.01 |
| Cluster 6 | −0.04 |
| Constant | 3.56*** |
| Observations | 1,045 |

Significant levels: *** $p<0.01$; ** $p<0.05$; * $p<0.1$.
*Notes*: Regression is clustered to estimate robust standard errors.

The regression results show that the information quality index positively affects consumers' PTB NGT wine. Specifically, for each additional point of the information quality index, the propensity to purchase increases by 0.56 on average, assuming all other variables remain constant. This finding suggests that a more accurate information may encourage Italian consumers to purchase of NGT wine, reinforcing the importance of information in the decision to purchase this type of food products.

Regarding consumer knowledge, proxied by an index with values of 1 (underestimates knowledge), 2 (correct estimate), and 3 (overestimates knowledge), the results show that both underestimation and overestimation reduce the propensity to purchase NGT wine. As for the socioeconomic profiles of the respondents, the results reveal positive and significant coefficients only for Cluster 2 and Cluster 4, with Cluster 1 serving as the baseline (that is keeping the intercept equal to 3.53). As previously mentioned, Cluster 1 (the baseline) primarily consists of male respondents, around 28 years old, with high school education, and an average yearly

income between 10,000 and 20,000 euros. The second profile (Cluster 2) represents a group of respondents that are on average 32-years-old women, graduates, with an average annual income of 20-25,000 euros. This group's PTB increases on average by 0.28 points compared to the baseline profile, assuming that the quality of information and the accuracy of consumer knowledge remain constant. Similarly, Cluster 4 also increases the PTB, shifting the intercept by 0.36 with respect to the baseline. This group is averagely composed of men in their forties, graduates, with an annual income ranging between 30,000 and 40,000 euros.

In summary, all else being equal, higher income and education significantly shift consumer preferences towards purchasing NGT wine. Figure 9, which depicts the marginal effects of clusters, provides a clearer view of how socioeconomic profiles impact consumers' PTB.

*Figure 9 - Predictive margins of Clusters with 95% Cis*
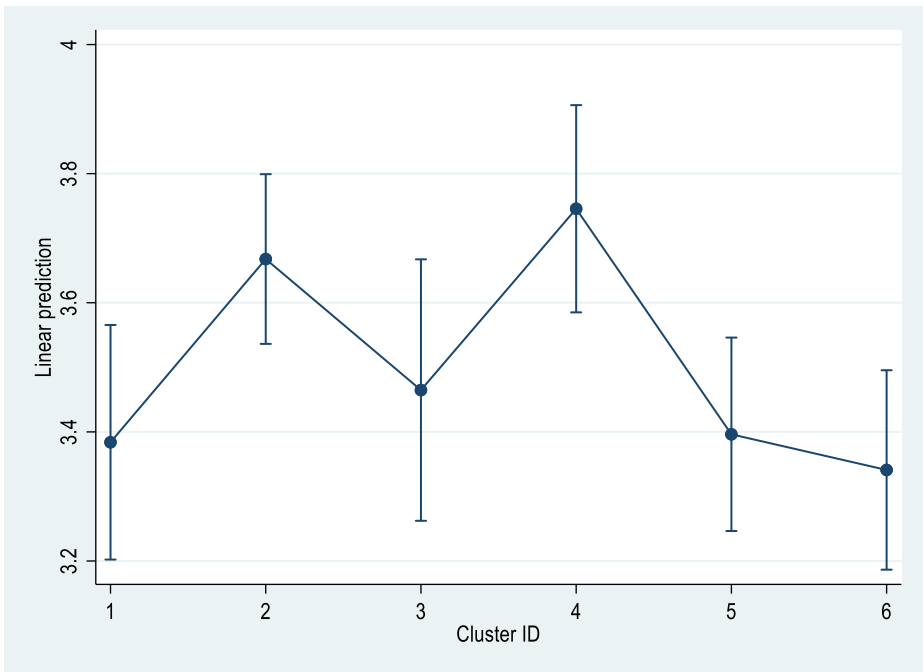


*Source*: Own elaboration on survey data.

## Conclusions

Our findings indicate that information plays a central role in consumer purchase decisions. More specifically, the quality of information, defined as the quality of the information channel and its frequency of use, significantly increases the likelihood of purchasing NGT wine. This aligns with Wunderlich (2019), who suggests that high-quality information enables consumers to make more informed decisions that align with their beliefs.

Additionally, we observed that access to adequate information allows individuals to gain a deeper understanding of complex topics like NGTs. This is crucial because our study highlights that a multifaceted narrative about NGTs tends to confuse consumers, leading them to either underestimate or overestimate their actual knowledge. This misperception creates further barriers to purchasing decisions.

Our conclusions are also in line with the study by Hwang and Nam (2021), which emphasises how an imbalance between subjective and objective knowledge can lead to poor decision-making. Moreover, we found that trust in information sources positively influences consumers, encouraging a greater propensity to buy NGT products. One of the main limitations of this analysis is that it focuses only on certain socio-economic characteristics, which we selected based on our assessment of their relevance to the propensity to purchase NGT wine. While the results are robust, this choice may have excluded other influential factors. Further analyses will follow this initial study to explore these relationships in greater depth.

In conclusion, the dissemination of transparent and accurate information is key to promoting consumer understanding of NGTs. As our study shows, consumer attitudes and purchase intentions are shaped by the level of their knowledge, and any biases or misunderstandings can hinder the development of a market for these products. Therefore, it will be essential to promote communication from authoritative sources and ensure its widespread distribution. To support this, policymakers should consider implementing frameworks that facilitate access to accurate information, encourage reliable sources, and ensure that communication strategies are clear and accessible to all consumers. This could include developing educational programs, regulatory guidelines for information accuracy, and creating platforms that ensure transparency.

While this study provides valuable insights into the barriers to the adoption of NGTs in agriculture, it is important to note that the focus on the consumer side represents a limitation. Market resistance, driven by consumer reluctance to accept wine products, is a significant challenge. However, the willingness of farmers to invest in these new techniques is also a crucial factor that warrants further exploration. Barriers may stem from farmers' reluctance

to adopt technologies, as they would have to bear the costs of introducing new technologies whose productive results are still uncertain today. Future research that includes both consumer and producer perspectives could provide a more comprehensive understanding of the factors influencing the adoption of NGTs and offer valuable contributions to the sector.

Despite its limitations, this study serves as a preliminary effort to assess whether Italian consumers would be inclined to purchase these products. A future analysis could explore how much they would be willing to pay for NGT wine, considering the importance they place on factors such as environmental sustainability and food safety.

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