

## Research Article

# From Roots to Leaves: Understanding Consumer Acceptance in Implementing Climate-Resilient Strategies in Viticulture

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This study investigates consumer perceptions and acceptance of innovative strategies implemented to counter the effects of climate change in the wine industry. The acceptance of wines derived from grapes grown using four different vineyard management practices—kaolin application, use of plant growth regulators, introduction of resilient rootstocks, and fungus-resistant grape varieties (PIWI)—is analyzed. Utilizing a latent profile analysis, the study identifies five distinct consumer profiles, each displaying unique sensitivities and perceptions towards climate change threats. The findings reveal notable variations in consumers' willingness to accept these innovations. Additionally, the study offers insights into how these preferences influence the marketability of wines produced using these innovative techniques. The overall results depict heterogeneous acceptance of these practices. Consumers seem more inclined to choose wines derived from vines with innovative rootstocks and those treated with kaolin. The acceptance for PIWI varieties and PGR is comparatively marginal. The outcomes of this study provide valuable insights for winegrowers, policymakers, and other industry stakeholders on effectively implementing and communicating these solutions. Overall, the research findings contribute significantly to understanding consumer behavior within the context of climate change in the wine industry, presenting substantial implications for sustainable viticulture practices and wine marketing strategies.

## 1. Introduction

In the last years, the increasing global warming has progressively modified landscape and growing techniques of many cultivated plants. Similarly, rising temperatures, changes in rainfall patterns, and extreme weather events like droughts and floods are affecting grapevines' growth and quality [1, 2]. Indeed, the grapevines are highly sensitive to temperature and moisture levels, and any significant change in these factors can have a severe impact on the crop yield and quality of the wine [3]. Thus, climate change has had a significant impact on the wine industry [4, 5]. Climate change is adversely affecting the wine industry by causing the loss of traditional grape-growing regions that are already experiencing its impacts [6, 7] since warmer temperatures

are causing grapes to ripen earlier, leading to a reduction in the wine's complexity and flavor [8].

In response to these challenges, the wine industry has turned to a combination of technological advancements, novel cultivation techniques, and varieties to mitigate the impacts of climate change and maintain the quality of their wine production [9, 10]. Innovative solutions have been developed to allow winegrowers to adapt their crop management systems to the changing climate.

One such innovation is the use of kaolin, a clay mineral, as a crop protectant. Kaolin is applied to the surface of the grapevines, creating a protective layer that reflects sunlight and reduces heat stress, effectively reducing the overall temperature of the grapevine [11]. Additionally, plant growth regulators (PGRs), including auxins, cytokinins, and

gibberellins, are naturally occurring hormones that can influence grapevine development stages, from bud break to berry development and ripening. Applied strategically, PGRs allow winegrowers to manage the grapevine growth cycle and ripening process, despite the changes in climate patterns [12]. Further, the introduction of innovative rootstocks is emerging as a prominent strategy. Rootstocks bred for specific resilience traits, such as greater resistance to salinity and reduced water demand, can help grapevines better withstand extreme weather conditions. This approach could not only sustain yield and wine quality under changing climate but also enable cultivation in previously unsuitable regions [13]. Another significant breakthrough in this space is the use of fungus-resistant grape varieties hereinafter defined as PIWI (Pilzwiderstandsfähige). These varieties are bred to have increased resistance to common vine diseases, thus reducing the need for frequent pesticide applications. This not only helps winegrowers cope with increased pest pressures due to climate change but also reduces the environmental impact of viticulture [14].

While these innovative strategies show promise in addressing the challenges posed by climate change, their adoption does not guarantee market success. The acceptance and demand from consumers play a significant role in determining their ultimate impact on the wine industry. For instance, although the application of kaolin does not directly interfere with the grape's inherent characteristics or the wine-making process, its visual impact on the plants could raise questions about the naturalness of the cultivation process among some consumers. Similarly, the use of PGRs, while scientifically sound and beneficial for adapting to climate change, may raise more concerns as PGRs may be viewed as a form of "chemical intervention." Introduction of new rootstocks, particularly those developed through advanced breeding techniques, can be seen as a deviation from traditional practices. However, given that the changes are not directly visible, they may be more readily accepted if the wines produced maintain their quality and flavor profiles. Finally, the use of PIWI grape varieties could have the most noticeable impact on consumer perception [14]. Indeed, while these varieties are beneficial in terms of reducing pesticide use, consumers who value the unique characteristics associated with specific grape varieties might have reservations about these new types.

Therefore, while these innovations offer potential solutions to the challenges of climate change, it is crucial to understand that their adoption may affect consumer perceptions and preferences. Indeed, any innovative strategy may prove economically unsustainable if it fails to gain consumer approval, regardless of its technical efficacy. Moreover, it is also necessary to identify if there are specific segments of consumers who are more accepting of these innovations. By understanding consumer segmentation, we can target our efforts more effectively, tailor the communication strategies for different consumer segments, and develop products that better meet their needs and preferences [15, 16]. Indeed, consumer segmentation offers several benefits for producers as well. Firstly, it enables targeted

marketing efforts, allowing producers to focus resources and messages on consumer segments more receptive to agricultural innovations. Secondly, it facilitates tailored product development, aligning innovations with the specific preferences and needs of distinct consumer groups. This optimization of resources and strategies not only enhances profitability [17] but also mitigates risks by diversifying the consumer base.

In light of these premises, the current paper aims to address these issues. Specifically, it aims to investigate whether there are variations in consumer perceptions and acceptance among different innovative climate change adaptation strategies in the wine industry. Additionally, it seeks to delineate consumer profiles based on their acceptance of these innovations.

To accomplish the overarching objective, we conducted a latent profile analysis (LPA) focused on consumers' preferences for wines produced from grapes obtained through more sustainable vineyard management practices [18]. The findings of this paper will help winegrowers, policy-makers, and other industry stakeholders implement and communicate these innovative solutions, thereby contributing to the resilience of the wine industry in the face of climate change.

The remainder of the paper is structured as follows: Section 2 describes the main contribution of current empirical evidence on sustainable vineyard practices and consumer preferences. Section 3 provides a description of survey design and data analysis. Section 4 reports main results by analyzing the latent profile of membership and assessing consumer characteristics. Section 5 discusses the results by connecting them with the existing literature of consumer acceptance of biological innovations and technical practices useful to reduce the climate change impacts. Section six concludes the paper by presenting the main limitation of the study, managerial and marketing implication, as well as the novelty of the study, and provides useful insights to develop further research.

## 2. Study Background and Research Hypotheses

In recent years, the impact of climate change has been pushing agriculture towards the adoption of innovative production techniques aimed at countering the negative effects of climate change [2]. Viticulture is one of the food sectors most affected by climate change and the negative effects it generates [19].

Many Southern European countries, which traditionally are major wine producers, risk-reducing vineyard surface, leading to negative externalities related to the loss of public goods associated with viticulture such as natural landscapes and ecosystem services [5, 20]. Accordingly, in recent years, several innovative production practices have been studied to safeguard traditional grape production areas in this region [9, 10].

However, the literature suggests that consumers are not always inclined to accept food products obtained through the use of innovative production techniques, and wine is no exception [19, 21, 22]. Indeed, besides the intrinsic sensory

properties of the product, consumer's perception of wine may depend on extrinsic aspects, such as the innovativeness or naturalness of the production practices [23].

Previous studies have analyzed consumer perceptions of environmentally sustainable practices in viticulture, such as organic production. These studies suggest that consumers' perception of the naturalness of practices adopted by organic wine producers, or the reduction in pesticide use, positively affects consumer preferences [24–27]. Moreover, despite being crucial to understand the willingness of producers to adopt innovative practices, knowledge of market responses from the consumer's perspective is recommended since any innovative strategy may be economically unsustainable if it is not approved by consumers.

In terms of consumer preferences, research suggests that consumers generally prefer grapes that are free from chemical residues and are produced using sustainable and environmentally friendly methods [28–30]. Therefore, it is possible that consumers may have a positive perception of grapes produced using kaolin. In addition, some consumers might not be familiar with kaolin or might prefer grapes that are not treated with any substances, even if they are natural. Moreover, its visual impact on the plants could raise questions about the naturalness of the cultivation process among some consumers.

(H1): in this respect, it is well worth eliciting consumer acceptability of plants treated with kaolin.

Additionally, research on consumer response to plant growth regulators in wine is quite limited. However, some studies have investigated consumer attitudes and preferences towards wines produced using different agricultural practices, including the use of synthetic chemicals and organic farming methods [31, 32]. Overall, research suggests that consumers generally prefer wines that are produced using sustainable and environmentally friendly methods, such as organic or biodynamic farming [33–35]. Consumers may also be concerned about the potential health effects of synthetic chemical residues in wine [36]; therefore, it is possible that consumers may have a negative perception of wine produced using plant growth regulators if they perceive these practices to be unsustainable or harmful to the environment or human health.

(H2): considering this premise, the present study also aims at exploring the consumer response to plant growth regulators in wine since this topic is rather limited in the literature.

Empirical evidence demonstrates that the implementation of innovative rootstocks can help maintain plant water balance and improve crop performance [37]. The reduction in water usage aligns well with growing consumer demand for more sustainable and environmentally friendly products [38]. As awareness about environmental issues increases, many consumers are becoming more conscious of their purchasing decisions and are looking for products that minimize environmental harm [31]. Therefore, wines produced using drought-tolerant rootstocks may be viewed

more favorably due to their lower environmental impact. On the other side, introduction of new rootstocks can be seen as a deviation from traditional practices.

(H3): for the abovementioned reasons, it becomes interesting to verify the consumer acceptance of wine deriving from vines raised on nontraditional rootstocks.

Finally, recently scientists have provided the possibility of growing new hybrids to replace the traditional grape varieties as an alternative solution to adapting to the climate changes. These are called PIWI (Pilzwiderstandsfähige) varieties, a short name to indicate “fungus-resistant grape varieties. However, it is important to note that PIWI varieties are still relatively unknown outside of certain regions, and some consumers may still prefer traditional grape varieties [39, 40]. Additionally, there may be challenges in marketing PIWI wines to consumers who are unfamiliar with these varieties or who may be skeptical of their quality compared to traditional grape varieties [27]. Their market share is still relatively small, and their acceptance may vary by region and individual taste preferences [19].

(H4): overall, there is some evidence of growing interest in PIWI varieties among certain segments of wine consumers.

These practices encompass a spectrum of approaches aimed at addressing the impact of climate change on viticulture, ranging from the grapevines' roots to their leaves. Together, they offer effective interventions to address diverse aspects of climate change challenges while catering to a wide range of consumer attitudes towards naturalness and technical intervention in wine production. However, a comprehensive study investigating the consumer acceptability of these various agricultural techniques, specifically aimed at mitigating the negative effects of climate change on viticulture, is currently lacking to the best of our knowledge.

Based on this background, the current study aims to investigate consumer's acceptability for four different innovative production practices in viticulture: (i) kaolin application, (ii) the use of plant growth regulators (PGRs), (iii) the introduction of resilient rootstocks, and (iv) PIWI grape varieties' cultivation.

Findings from this study can serve as important inputs for policy-makers, winegrowers, and other stakeholders in developing future strategies for viticulture in the context of climate change. Moreover, in today's digital age, consumers have access to a multitude of information sources. Therefore, even if firms do not communicate production innovations directly, revealed consumer preferences may indirectly encourage the adoption of such innovative viticultural strategies aiming at increasing viticulture resilience to the negative consequences of climate change.

The following sections provide an in-depth exploration of the selected strategies for addressing climate change challenges in the viticulture industry and their potential impact on consumer perceptions, particularly in relation to the perceived naturalness of the wine.

### 3. Methods

**3.1. Participants and Procedure.** To investigate consumer acceptance of various innovative vineyard practices, we administered a survey to a convenience sample of 810 wine consumers in Italy, a country renowned for its rich wine tradition [41]. The sample size of 800 was chosen to satisfy an effect size  $f^2$  of 0.12, thereby achieving a statistical power of 90% and an alpha of 0.05, as per the a priori power analysis conducted using *G \* Power* 3.1 [42]. Responses were collected via the Google Forms platform and employing a snowball-sampling technique.

The questionnaire was structured into three primary sections. The first section served as a filter to identify habitual wine consumers. In the second section, acceptance levels for four vineyard practices (namely, kaolin, plant growth regulators, innovative rootstocks, and PIWI) were assessed. These different agronomic strategies were selected through an extensive analysis of scientific literature, consultations expert, and considerations of varying levels of naturalness and intervention in the grape cultivation process.

After presenting a brief overview of the issues faced by vineyards due to climate change and providing a nontechnical description of the four practices designed to address these challenges, participants were asked to rate their (i) willingness to accept each practice (e.g., “Would you support the use of this technique in viticulture?”); (ii) willingness to consume wine produced using each specific practice (e.g., “Would you be willing to consume wine that comes from a vineyard treated with this technique?”); and (iii) willingness to pay a premium for wine made using each practice (e.g., “Would you be willing to pay a higher price for wine produced with this innovation to support some of the costs incurred by vine growers?”). These three dimensions of acceptance were custom-designed for this study to capture varying levels of consumer engagement with the innovative practices. Responses were collected on a Likert scale ranging from 1 (“absolutely not”) to 5 (“absolutely yes”) and were averaged to generate a comprehensive measure of acceptance for each practice, providing a holistic view of consumer response. The reliability of these acceptance measures was assessed using Cronbach’s  $\alpha$ , with calculated values ranging from 0.88 to 0.94, indicating strong internal consistency and reliability in the acceptance measurement. The third and final section of the questionnaire aimed to gather sociodemographic and general information about the participants.

**3.2. Statistical Analysis.** To address RQ1 and compare the acceptance scores across four vineyard practices, we conducted a repeated-measures analysis of variance (ANOVA). This approach allowed us to test the null hypothesis that all practices, namely, kaolin, plant growth regulators, rootstocks, and PIWI, have the same mean acceptance score. Upon finding a significant overall effect, we employed post hoc pairwise comparisons with Bonferroni correction to control for Type I error across multiple tests. This step was crucial to pinpoint which practices, if any, differed significantly in acceptance from the others.

A latent profile analysis (LPA) was then employed as the main statistical analysis in the present study, in order to identify segments of consumers based on their preference for wine made with different vineyard practices (i.e., kaolin, plant growth regulators, rootstocks, and PIWI).

LPA is a categorical latent variable approach that focuses on identifying latent subpopulations within a population, based on a certain set of continuous indicators [18]. In our study, these indicators were the acceptance levels of the four vineyard practices mentioned above, which were used to identify distinct profiles or subgroups of wine consumers. LPA thus assumes that people can be typed with varying degrees of probabilities into categories that have different configural profiles of personal characteristics. Hence, in LPA, the heterogeneity in preferences is assumed between segments, while consumers within a segment are assumed to be homogeneous.

After identifying the optimal number of latent profiles by comparing Akaike and Bayesian information criteria (AIC and BIC), we conducted an analysis of covariates as predictors of latent profile membership, in order to assess whether certain consumer characteristics were associated with the latent profiles. Specifically, the three-step maximum likelihood (ML) approach proposed by Vermunt [43] was employed.

This method has several advantages over other approaches to analyzing covariate effects in LPA. Firstly, it accounts for the uncertainty in the latent class assignment, which can affect the estimation of the covariate effects. Secondly, it maintains the integrity of the profiles when the covariates are added in the model [44]. All statistical analyses were performed using Stata 18. The three-step ML approach was not directly implemented in Stata, and it was performed using the community-contributed software STEP3 [45].

### 4. Results

**4.1. Descriptive Statistics.** Our sample consisted of 810 Italian wine consumers, 64% of whom were aged between 19 and 34 years. This suggests an overrepresentation of younger individuals when compared with the general population of wine consumers. The sample exhibited a nearly even gender distribution with 51% males and 49% females. The majority of participants reported annual household incomes in the range of 10,000€ to 30,000€, comprising 50% of the sample. With regard to wine consumption frequency, most of the respondents (74%) reported consuming wine at least once a week, with 18% consuming wine daily. The remaining 26% had a less frequent consumption pattern, ranging from once a month to once a year. The main descriptive statistics of the sample are presented in Table 1.

**4.2. Consumer Acceptance of Vineyard Practices.** Prior to conducting the LPA, a preliminary analysis of variance (ANOVA) for repeated measures was conducted on the entire sample to investigate the effect of vineyard practices on consumers’ acceptance (RQ1).

TABLE 1: Descriptive statistics.

Variable	N	Percent (%)
<i>Age</i>		
18	3	0
19–34	519	64
35–54	191	24
55–73	92	11
74–93	5	1
<i>Gender</i>		
Male	417	51
Female	393	49
<i>Annual household income</i>		
<10,000€	90	12
10,000–20,000€	172	23
20,000–30,000€	195	27
30,000–40,000€	113	15
40,000–50,000€	65	9
50,000–60,000€	37	5
60,000–70,000€	29	4
>70,000€	39	5
<i>Frequency of wine consumption</i>		
Once a year	19	2
Once every 6 months	42	6
Once every 3 months	20	3
Once a month	112	15
Once a week	427	56
Every day	139	18

The results showed a significant main effect of vineyard practices ( $F(3, 2427) = 348, p < 0.001$ ), indicating that not all practices were accepted equally, with some practices seeing significantly higher acceptance than others. Specifically, the Bonferroni post hoc test revealed a clear ranking of practices in terms of consumer acceptance. Wine derived from innovative rootstocks was most accepted by consumers, with the highest average score. This was followed by kaolin, then PIWI, with plant growth regulators having the lowest acceptance (Table 2).

These initial findings provided a foundation for the subsequent LPA, allowing us to explore potential subgroups or profiles within our sample that might exhibit different acceptance patterns across the four vineyard practices.

**4.3. Latent Profile Analysis.** LPA was employed to identify distinct segments of consumers based on their acceptance of wine made with different vineyard practices, namely, kaolin, plant growth regulators, rootstocks, and PIWI (RQ2). The results of the LPA were assessed using AIC and BIC, which indicated five profiles as the best grouping solution (Table 3).

LPA identified five distinct profiles of consumer acceptance, each representing a subgroup of consumers with a distinct pattern of acceptance for the four vineyard practices. These profiles were named based on their characteristic acceptance patterns and are presented in Table 4 and Figure 1.

Firstly, “Skeptics” represented 14% of the sample. This profile displayed relatively low acceptance for most practices, with a notably higher acceptance for rootstocks. This suggests a preference for more traditional or familiar wine production methods.

TABLE 2: ANOVA post hoc results.

Practice	Mean value	95% confidence intervals
Rootstocks	3.88 <sup>c</sup>	3.81–3.95
Kaolin	3.12 <sup>a</sup>	3.05–3.19
PIWI	2.61 <sup>d</sup>	2.54–2.67
Plant growth regulators	2.46 <sup>b</sup>	2.39–2.52

Notes. \*Likert scale, from 1 (“absolutely not”) to 5 (“absolutely yes”); SE = 0.034. Margins not sharing the same letter are significantly different at the 5% level.

TABLE 3: LPA model fit summary.

Profiles	DF	LL	AIC	BIC
1	14	−4,472.169	8,972.339	9,038.097
2	19	−4,446.044	8,930.088	9,019.332
3	24	−4,413.957	8,875.914	8,988.643
4	29	−4,379.214	8,816.427	8,952.641
5	34	−4,304.632	8,677.264	8,836.963
6	39	−4,353.918	8,785.836	8,969.020
7	44	−4,325.879	8,739.757	8,946.427

Notes. DF = degrees of freedom; LL = log likelihood; AIC = Akaike information criterion; BIC = Bayesian information criterion. Estimates for 810 observations.

The “Traditionalists,” comprising 27% of the sample, showed moderate acceptance for all four practices. This moderate approach might reflect a value for the continuity of proven, tested vineyard practices and a balanced view of innovation, recognizing the need for adaptation but wary of extreme departures from tradition.

The “Naturalists” constituted 13% of the sample. These consumers showed a high acceptance for drought-resistant rootstocks and kaolin. These methods are both generally considered environmentally friendly, implying a consumer preference for practices that align with more sustainable practices and/or perceived as less invasive for the environment and the wine’s flavor profile.

The “Modernists,” the largest group representing 32% of the sample, had higher acceptance for plant growth regulators and PIWI compared to the previous three groups. This pattern might suggest a preference for practices that reflect research-led innovation and potentially showing acceptance of technology and science as tools to adapt to changing conditions and improve wine production.

Finally, “Enthusiasts,” representing 14% of the sample, demonstrated high acceptance for all vineyard practices. This suggests an openness to diverse methods of wine production, likely driven by a curiosity and a willingness to support innovative approaches to wine making.

In order to investigate the association between consumer characteristics and the identified latent profiles, an analysis of covariates was conducted. The covariate analysis revealed significant associations between consumer characteristics and the identified latent profiles. The base outcome for comparison was the “Modernists” profile, as this was the largest group.

Notably, the “Skeptics,” “Traditionalists,” and “Naturalists” profiles were generally composed of older consumers compared to “Modernists.” This finding suggests that age

TABLE 4: Estimated margins of indicator variables for each profile.

	Profile 1 Skeptics (14%) Margin (SE)	Profile 2 Traditionalists (27%) Margin (SE)	Profile 3 Naturalists (13%) Margin (SE)	Profile 4 Modernists (32%) Margin (SE)	Profile 5 Enthusiasts (14%) Margin (SE)
Rootstocks	3.61 (0.10) <sup>a</sup>	3.80 (0.06) <sup>ab</sup>	3.95 (0.08) <sup>bc</sup>	3.84 (0.06) <sup>ab</sup>	4.27 (0.09) <sup>c</sup>
Kaolin	1.87 (0.06) <sup>a</sup>	3.02 (0.06) <sup>b</sup>	3.42 (0.07) <sup>cd</sup>	3.28 (0.05) <sup>c</sup>	3.69 (0.10) <sup>d</sup>
PIWI	2.14 (0.11) <sup>a</sup>	2.46 (0.07) <sup>a</sup>	2.21 (0.10) <sup>a</sup>	2.79 (0.06) <sup>b</sup>	3.21 (0.12) <sup>c</sup>
PGR	1.03 (0.01) <sup>a</sup>	1.98 (0.01) <sup>b</sup>	1.04 (0.01) <sup>a</sup>	3.08 (0.02) <sup>c</sup>	4.45 (0.04) <sup>d</sup>

Notes. Different letters within a row indicate significant differences between segments at the 5% level.

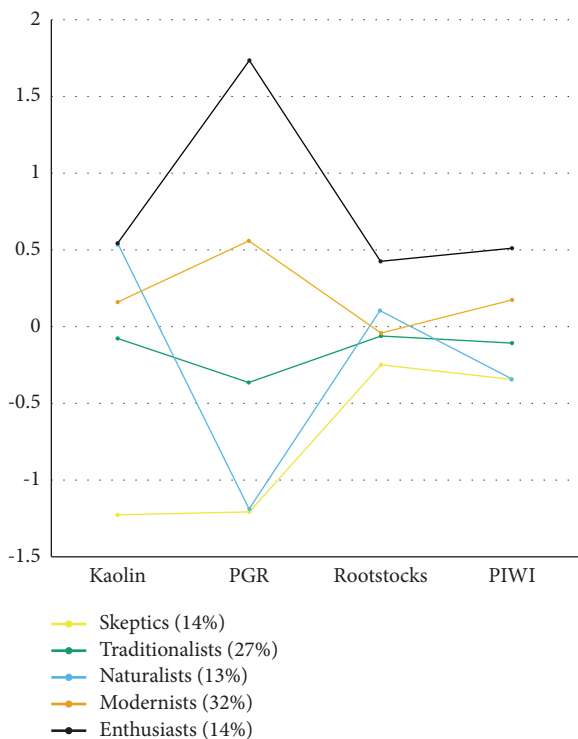


FIGURE 1: Line graph comparing profiles on indicator variables (z-scores).

plays a crucial role in the acceptance of new vineyard practices, with older consumers seemingly more resistant to certain types of innovations.

“Skeptics” and “Naturalists” were found to have lower average incomes than “Modernists.” Examining wine-related behaviors, “Traditionalists” were more likely to consume local and regional wines, reflecting a preference for familiar products and perhaps indicating an affinity for traditional wine production methods. Contrarily, the “Enthusiasts” group reported consuming less local wine, suggesting a more adventurous palate and openness to trying wines from diverse regions or produced through new practices. Interestingly, the “Naturalists” profile reported consuming wine more frequently and was willing to spend more on average for a bottle of wine compared to “Modernists.” This suggests a segment of consumers who highly value the wine they consume, prioritizing quality and potentially environmental impact, which could make them more accepting of innovations viewed as enhancing these factors.

Tables 5 and 6 report and summarize the descriptive characteristics for each of the five identified groups, while Figure 2 shows how the average price spent for a bottle of wine and wine consumption frequency (and their interplay) influence the probability of belonging to each profile. The contour plots illustrate the marginal posterior probabilities of group membership as functions of the average price spent per bottle of wine, the frequency of wine consumption, as well as their interaction effect. In this analysis, we replicated the methodology of the previous covariate analysis by applying the three-step ML approach [43], ensuring consistency across statistical procedures.

## 5. Discussion

This study set out to examine the acceptance of innovative vineyard practices capable of mitigating and adapting to the adverse effects of climate change. We focused on four strategies involving all major parts of the plant, from roots to leaves. The primary result of our research allowed us to provide evidence on consumers’ acceptance of these innovative climate change adaptation strategies. Moreover, the study succeeds in identifying and characterizing different consumer segments in terms of their acceptance of these innovations, thus creating multiple clusters that display heterogeneous acceptance of these innovative techniques. Specifically, findings from this study revealed that consumers prefer wine made with innovative rootstocks, followed by kaolin, PIWI, and PGRs, respectively. In terms of consumer preferences, wines derived from innovative rootstocks emerged as particularly attractive maybe because historical pest emergencies like phylloxera led producers to adopt new rootstocks, gradually encouraging consumer acceptance of wines stemming from this innovation [14]. Hence, consumers seemingly perceive this as a nonintrusive, climate-resilient technique. Moreover, it was found that kaolin, a product naturally derived from clay and used to decrease grape temperature [46], garnered significant consumer appeal, likely perceived as akin to traditional organic fungicides, despite its distinct function. Even though recent emphasis is on the role of fungus-resistant grapes, our study detected minimal interest in PIWI wines. This might be due to consumer confusion, with many considering this practice akin to transgenic innovation. Consequently, the adoption of fungus-resistant grape varieties seems to have little

TABLE 5: Covariate analysis results, with “Modernists” (32%) set as the base outcome.

	Skeptics (14%)	Traditionalists (27%)	Naturalists (13%)	Enthusiasts (14%)
Age	0.931***	0.248*	0.637***	-0.018
Income	-0.125*	0.004	-0.118*	0.065
Woman	0.045	0.149	-0.016	0.133
Local wine	0.377	0.363*	0.134	-0.453*
Wine freq.	0.036	-0.001	0.184*	0.078
Wine price	0.040	0.024	0.048*	0.035
Constant	-3.551***	-1.007*	-3.536***	-2.248***

Notes. Results in multinomial log-odds. \* $p < 0.10$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

TABLE 6: Main sociodemographic characteristics and habits of each group.

	Skeptics	Traditionalists	Naturalists	Enthusiasts	Modernist
Sociodemographic characteristics	Older Low income	Older —	Older Low income	—	Younger High income
Habits		Local wines	High-frequency high price	International wines	Medium price

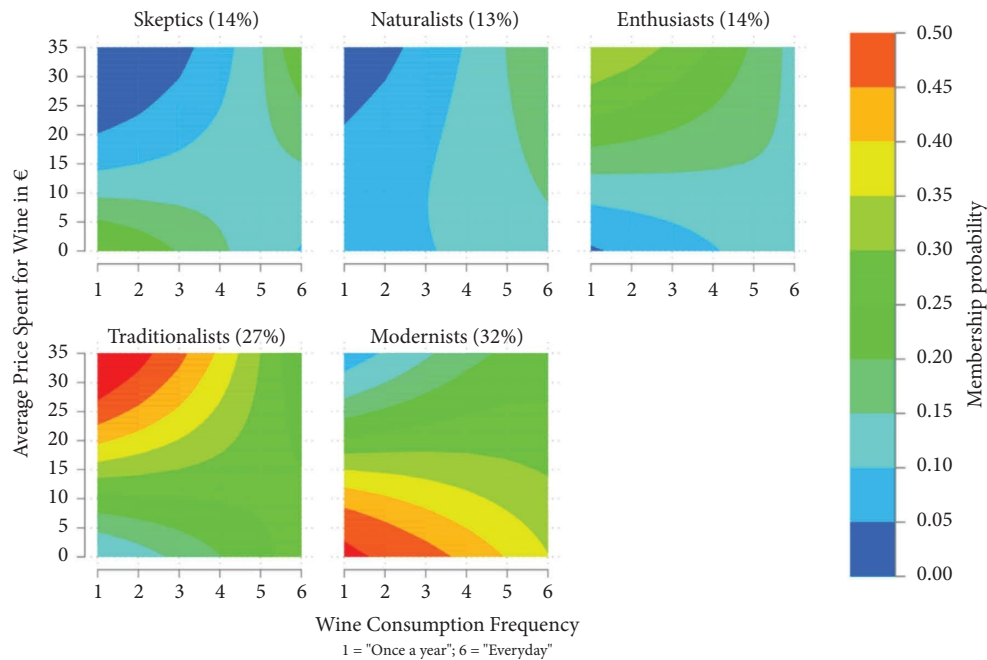


FIGURE 2: Predicted posterior probability of belonging to each profile by wine consumption frequency and average price spent for a bottle of wine.

influence on consumer acceptance, even though these could potentially reduce the use of agrochemicals in grapevines [47]. Hence, while fungus-resistant grape varieties undeniably constitute a pivotal innovation in the evolving landscape of the wine industry, their significance remains confined to a relatively small and specific group of consumers [19]. This limited adoption may be attributed, in part, to a lack of clarity and information regarding the origins of PIWI wine varieties [26]. Finally, the acceptance of plant growth regulator in vineyard management practices received the lowest score. This outcome appears quite consistent with recent studies indicating how consumers largely prefer food products with no artificial growth hormone [48]. Therefore, the generalized

perception about meat consumers is confirmed even in the case of the PGR in grapevine growing since they are considered the least important tool to reduce the climate change [49]. Additionally, the study findings revealed that ‘Skeptics,’ ‘Traditionalists,’ and ‘Naturalists’ profiles were generally composed of older consumers compared to ‘Modernists,’ thus meaning that older consumers are more reluctant to certain types of innovations. This finding is supported by the existing literature since past research showed that older consumers often display lower acceptance of novel wines when technological innovations are introduced in the wine industry [50]. Furthermore, in traditional wine-producing countries, Castellini and Samoggia [51] found younger consumers more



enthusiastic towards the acceptance of novel wines [51]. Conversely to our result, Galati and colleagues [36] found that younger consumers prefer more frequently natural wines than older consumers. Moreover, looking at the wine-related behaviors, “Traditionalists” consumers, meaning consumers who showed moderate acceptance for all four practices, showed a preference for traditional and local wine production methods. This finding is in line with previous studies, which showed underscored consumer ethnocentrism among traditional wine consumers [52, 53]. On the other hand, the “Enthusiasts” group indicated a lower consumption of local wine. This probably occurs because this kind of consumer shows a high propensity to openness and accepting innovativeness [54], such as adventurous taste and a willingness to explore wines from imported varieties or made using innovative methods. Interestingly, the “Naturalists” profile is willing to spend more on average for a bottle of wine compared to “Modernists.” This suggests a segment of consumers who highly value the wine they consume, prioritizing quality and potential environmental impact, which could make them more accepting of innovations viewed as enhancing these factors. A recent study has shown that “Naturalist” consumers are willing to pay a price premium for a more sustainable wine, to encourage the adoption of more sustainable practices [55].

*5.1. Study Implications.* The empirical results of this study have significant implications both in theory and practice. In terms of theory, this study contributes to the literature on consumer perception of technological innovations in the agrifood sector by providing preliminary evidence regarding consumer preferences for agricultural practices that aim to enhance the resilience of traditional vineyards to the adverse effects of climate change. While recent literature has offered some empirical evidence regarding consumer preferences for wines produced through environmentally sustainable or less sustainable techniques [19], there is a lack of empirical findings concerning consumer preferences for agricultural practices aimed at increasing the resilience of traditional vineyards in the face of climate change consequences. Furthermore, the results of this study add to the scientific literature a detailed segmentation of consumers based on their preferences for these management techniques and the relationship between these preferences and certain socio-demographic variables.

The practical implications of this study are also noteworthy. Knowing the agricultural practices preferred by consumers can make it easier for vineyard owners to adopt specific practices. Conversely, policymakers can anticipate interventions to incentivize practices less preferred by consumers, which vineyard owners might be hesitant to adopt. Additionally, since the average consumer often lacks knowledge about the management practices underlying wine production, it might be beneficial to include information on the “most preferred” practice on the label to preserve the quantitative, qualitative, or landscape characteristics of a specific vineyard.

## 6. Conclusion

Climate change represents a critical issue for the wine industry. Wine consumers can aid in mitigating this concern by opting for wines produced by growers adopting innovative, climate-resilient viticulture practices.

The overall results depict heterogeneous acceptance of these practices. Nevertheless, consumers seem more inclined to choose wines derived from vines with innovative rootstocks and those treated with kaolin. The acceptance for PIWI varieties and PGR is comparatively marginal. However, when excluding traditionalists and skeptics, over half of the sample population showed a relative willingness to embrace such innovations. The results further demonstrate that this acceptance is positively correlated with younger age. Additionally, other covariates such as income, wine consumption frequency, wine price, and preference for locally produced wine have shown some significance.

The novelty of this paper lies in its exploration of consumer acceptance of climate-resilient viticulture practices through the lens of consumer segmentation. It unravels the complexities of consumer preferences and underlines the role that certain demographics play in this evolving situation.

This study holds helpful implications for producers and marketers. It emphasizes the need for effective communication about the benefits and safety of plant growth regulators and PIWI varieties to consumers. Grape growers and wine producers can improve the sustainability and quality of their products by responsibly using plant growth regulators, but at the same time, they need to carefully preserve consumer trust and preferences.

However, this study is not without its limitations. The use of convenience sampling used could introduce bias, as the participants may not be representative of the broader Italian wine consumer population. Furthermore, an overrepresentation of younger consumers may skew the data, limiting the extrapolation of these findings to a broader, more diverse audience. Nevertheless, given the exploratory nature of this study and considering the future consequences that some agronomic practices may have in the near future, we believe that having a sample composed of a younger population can help understand the evolving choices of future consumers.

Future research could focus on expanding the sample to include a more diverse age range, different consumer profiles, and individuals from various nationalities. This could offer a more comprehensive understanding of global consumer attitudes towards climate-resilient viticulture practices. Further studies could also delve into more nuanced consumer attitudes and behaviors regarding wines produced with climate-resilient innovations, leveraging qualitative research methods for a more in-depth understanding. Longitudinal studies could provide insights into how these attitudes and behaviors evolve over time, particularly as innovative viticulture practices continue to develop, and more information becomes available to consumers. Moreover, while our study identified distinct consumer profiles assessing their levels of acceptance for various vineyard



practices, we did not delve into the underlying reasons for these variations. This aspect warrants further investigation in future studies. Furthermore, future studies could delve into the willingness of producers to adopt such practices. Lastly, to refine marketing strategies, it would be worthwhile to explore the potential influence of communication approaches and labelling on consumer perception and acceptance of wines produced with climate-resilient strategies.

## Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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