Environmental Development 54 (2025) 101120

Contents lists available at ScienceDirect

Environmental Development

journal homepage: www.elsevier.com/locate/envdev

Nudging interventions to foster the reduction of pesticides in viticulture. Insights from Italian winegrowers

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ARTICLE INFO

Keywords:
Ecological transition
Green nudge
PiWi grapes
Mitigation of pesticides
Attitudinal characteristics

ABSTRACT

The demand for sustainable solutions to reduce the negative externalities of the agricultural production system is continuously growing. In the viticultural sector, one promising strategy to reduce the excessive use of pesticides is the adoption of fungus-resistant grape wine (PiWi) varieties. The current study explores the likelihood of adoption of PiWi varieties among a sample of professional winegrowers in Sicily (southern Italy). Specifically, applying an experimental between-subjects design, the present research explores whether providing two nudges (salience nudge and the same coupled with a social comparison one) increases winegrowers' intention to plant PiWi varieties in the upcoming five years. The findings show that both nudges positively affect the innovation adoption (+12% compared to the control group). Additionally, factors such as expected social and personal benefits and risk-taking behavior emerge as influential in the decision-making process for PiWi uptake. Outcomes suggest stakeholders interested in fostering the reduction of pesticides in viticulture to explore the potentials of nudge interventions further.

1. Introduction

There is an ongoing and heated debate among the international scientific and political communities on the issue of sustainable agriculture and the mitigation of the negative impacts that various production systems have on the environment, climate, and society (Nicolopoulou-Stamati et al., 2016; Zeweld et al., 2017; Keshavarz and Sharafi, 2023; Du et al., 2024). Global climate change and the accelerating depletion of natural resources underline the role of businesses, not least agricultural ones, in reducing negative externalities (Ansah and Sorooshian, 2019; Caicedo-Vargas et al., 2023; Xu et al., 2024).

Viticulture is one of the main causes of negative externalities in the agricultural sector due to the high use of pesticides at different grapevine phenological stages (Lorenz et al., 1995; Carvalho, 2017; Bavaresco and Squeri, 2022). Indeed, pesticides are often used by winegrowers to protect the harvest from plant diseases, especially downy mildew, powdery mildew, and botrytis, that can cause severe damage to grapevines (Pertot et al., 2017). Considering that worldwide 7.4 million hectares are devoted to grape growing and broadly 45% are located within European Union (OIV, 2022) these issues affect 2.2 million vineyard holdings only in the EU (Eurostat, 2024).

To reduce negative externalities caused by pesticide applications in agriculture, the European Union has set up over time a series of initiatives, including the European Directive 128/2009/EC on pesticide use reduction, and the Farm to Fork Strategy, aiming at a 50 percent reduction in the use of pesticides in agriculture by 2030, offering financial support to farms to adopt ecological schemes.

Among the various sustainable innovations to reduce the use of chemical pesticides in the wine sector is the adoption of fungus-

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https://doi.org/10.1016/j.envdev.2024.101120
Received 29 May 2024; Received in revised form 20 November 2024; Accepted 20 November 2024
Available online 28 November 2024

resistant wine grape varieties, also called PiWi varieties (Casanova-Gascón et al., 2019). These combine the positive oenological qualitative aspects of European *Vitis vinifera* with the agronomic high disease resistance of American or Asian *Vitis* such as *V. riparia, V. amurensis,* and V. *rupestris*. Specifically filling the gaps of *V. vinifera* which is particularly susceptible to diseases (Pedneault and Provost, 2016). In addition, according to the literature on climate projections, the Mediterranean area of Europe has been identified as one of the most important "Hot spots" in future climate change projections, which will be characterized by an increase in precipitation and the occurrence of extreme weather conditions (Migliore et al., 2019; Giorgi and Lionello, 2008). In the coming years, this could significantly influence the sensitivity of the vineyard to fungal diseases, especially downy mildew, and powdery mildew. Therefore, it is presumable that PiWi varieties could represent a valid alternative to face the negative impacts of climate change (Santos et al., 2020). Following Pertot et al. (2017), the adoption of these varieties could contribute to reducing the risk of loss of production, thanks to greater resistance to disease, and reduce production costs due to lower use of pesticides and consequently less labor. However, studies on farmers' adoption of PiWi grape varieties are still quite scant. Although it represents an alternative low-pesticide wine production system, farmers' adoption of fungus-resistant varieties is still not widespread among European winegrowers (Zachmann et al., 2023). To incentivize the adoption of agricultural practices in agriculture, the discussion on the role of information treatments, in the form of nudges has recently surged in the European political landscape (European Commission, 2022). However, to date, nudges are mainly studied to influence consumer behavior (Rainatto et al., 2024; Langen et al., 2022; Prelez et al., 2023), while limited evidence is available in the context of farmers' behavior. To the best of our knowledge, only one study has analysed the effects of nudging interventions on the adoption behavior of grapevine growers toward these varieties (Zachmann et al., 2023). Specifically, Zachmann et al. (2023), tested two types of salience nudges (personalized and general information) to encourage grapevine growers to adopt fungus-resistant varieties in Switzerland and found no statistically significant effect of these interventions on the adoption rate. However, it has also been highlighted that the effectiveness of nudges is highly dependent on the context (Wu and Paluck, 2021; von Kameke and Fischer, 2018). Therefore, it is presumable to hypothesize that in other geographical contexts, those more susceptible to climate change, among which the Mediterranean regions, the response to nudges by farmers may be different. Furthermore, from the study of Zachmann et al. (2023), it is unclear whether and to what extent other factors may affect the adoption of PiWi among winegrowers. Therefore, the current study has twofold objectives: *i*) measuring the impact of nudges on the likelihood of adoption of PiWi varieties among winegrowers operating in Sicily, a Mediterranean region of Southern Italy; and *ii*) detecting the core drivers and barriers in the likelihood of its adoption.

Regarding the former objective, we verify the effectiveness of two framing messages, identified in the literature as useful tools to gently guide farmers' behaviour. Specifically, a salience information on the environmental consequences of the overuse of pesticides in the vineyards and a social comparison nudge highlighting the behavior of other farmers in the same area are tested.

The study is developed as follows: first, the theoretical framework underpinning the research is presented, followed by methodological and results sections. Finally, discussions of the main findings and the conclusion of the study are outlined together with the implications, limitations, and future research avenues.

2. Theoretical framework

Several theoretical models have been developed to predict the adoption of innovation among economic actors, including farmers (Peshin et al., 2009, 2019). Among these, the theory of reasoned action (TRA) (Ajzen and Fishbein, 1980), the theory of planned behavior (TPB) (Ajzen, 1991), the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003) Diffusion of Innovations Theory (DOI) (Rogers, 2003) and the Technology Acceptance Model (TAM) (Davis, 1993), as well as the extensions of their original versions, can be considered the most applied theoretical models to predict farmers' innovation adoption (Mohr and Kühl, 2021). However, all these theoretical models assume that humans are rational and make decisions based on the characteristics of the innovation and its economic advantage, on the available information and on the characteristics of farmers. Conversely, a strand of research on sustainable innovation adoption supports the notion that farmers may be driven by both economic and non-economic motivations since sustainable practices go beyond the economic aspect and involve society at large, as well as farmers' prestige in the community (Aguilera et al., 2007; Aguinis and Glavas, 2012). Thus, sustainable innovation adoption may entail a balance between economic, social, and personal motives (Trujillo-Barrera et al., 2016). Furthermore, while economic, social, and personal motives are likely to have a positive influence on farmers' innovation adoption, an important barrier toward sustainable innovation adoption deals with farmers' risk attitude.

Therefore, the current study builds on Trujillo-Barrera and colleagues' (2016) theoretical framework, which examined expected economic, social, and personal rewards as driving forces for the adoption of sustainable innovations, while also identifying farmers' financial risk perception as a potential barrier. Specifically, the authors investigated financial risk tolerance as a moderator in the relationship between risk perception and adoption, as well as between economic rewards and adoption. However, compared to the theoretical model proposed by Trujillo-Barrera and colleagues in the present study the risk perception and tolerance scales are replaced by farmers' general attitudes toward risk, as winegrowers can deal with different sources of agricultural risks, not just the financial one. Indeed, the literature shows that farmers constantly face and manage different types of agricultural risks, namely production risks, marketing and price risks, financial risks, and risks in agriculture in general. (Huirne, 2003; Meraner and Finger, 2019; Meuwissen et al., 2001).

Furthermore, we considered nudge interventions as potential drivers to encourage the adoption of sustainable innovations, especially PiWi varieties. There is growing interest in using nudges in addition to conventional policy tools to advance the ecological transition (Enticott and Little, 2022; Benartzi et al., 2017). However, compared with conventional policy instruments, nudge succeeds in stimulating individuals' pro-environmental behavior in the short term, while also allowing cost-saving (Brown, 2018). In recent

years, there has been an increasing application of nudges among economic operators in business activities, such as in agriculture (Chabé-Ferret et al., 2019). Among the many typologies of nudges explored in the literature (Blumenthal-Barby and Burroughs, 2012), the two types among the most widely used to stimulate ecological transition in agriculture are salience nudge and salience coupled with a social comparison nudge (e.g. Peth et al., 2018; Boun My et al., 2022; Michels et al., 2023). The salience nudge involves the use of messages that elucidate the opportunity costs associated with a particular behaviour (Blumenthal-Barby and Burroughs, 2012). Its purpose is to underscore the consequences of a specific action (Pellegrin et al., 2018). The Social comparison nudge, on the other hand, entails providing informative messages about society's habits to encourage individuals to conform to the prevailing behaviour (Byerly et al., 2019). As pointed out in other studies, the combination of these two types of nudges could result in an effective strategy that matches the opportunity cost of a specific behaviour (salience nudge) by encouraging individuals to conform to the prevailing action (social comparison nudge) through the provision of informative messages about society habits (Peth et al., 2018; Peth and Muβhoff, 2020; Michels et al., 2023).

3. Methodology

3.1. Data collection

Data were collected through an online, between-subject experimental survey performed from March to November 2023, among 249 Sicilian professional viticultural farmers. Sicily was selected as a case study because it has the largest vineyard area in Italy (almost 100.000 ha), accounting for more than 14% of the country's total (ISTAT, 2022), and counts over 36.000 vineyard holdings (ISMEA, 2022). However, the Sicilian authorities have shown scepticism in including fungus-resistant varieties in the registers of authorized varieties, a view not necessarily shared by the local winegrowers. Therefore, the study aimed to evaluate how willing farmers are to adopt these PiWi varieties and to identify the factors that encourage or hinder winegrowers from making this decision.

Winegrowers were recruited for the study through invitations sent out via trade associations, wine cooperatives, and direct personal networks. The experimental survey was organized into consecutive phases (Fig. 1) managed *through* a dedicated platform. Participants were informed that the survey was meant for research purposes, their participation was voluntary, and could withdraw at any time.[1] Information on the farm was collected, such as the total farm area, the area devoted specifically to viticulture, and the slope of the vineyard. In addition, we collected information about organic certification by asking: "*Is your farm organically certified*?".

Then, after being randomly assigned to one of the sub-groups of the experiment, respondents were asked to rate their likelihood of adoption of PiWi varieties within the next five years on an anchored scale from 0 (0% likelihood) to 10 (100% likelihood). Before indicating their likelihood of adoption, the total sample received the following description of PiWi grape wines (translated from Italian): *"These vines are the result of multiple crossings between the European wine and American or Asian vines. They exhibit high resistance to fungal diseases, which reduces the need for plant protection products. The resulting wine has a flavor that is similar to that of the European variety used in the crossing (in blind tastings, many tasters have been unable to distinguish between them). However, it should be noted that the initial planting cost is high and phytosanitary treatments cannot be eliminated"*.

The two treatment groups, in addition to general information, received a salience nudge containing environmental information about the overuse of pesticides in agriculture (*Salience nudge group*) and the same salience nudge coupled with information regarding the level of adoption among other farmers in the same geographical area (*Salience & Social comparison nudge group*). Both information treatments were accompanied by pictures showing the environmental damages supposedly caused by pesticide overuse in vineyards (see Appendix).

Subsequently, different measures were collected to understand whether the adoption of sustainable practices in viticulture were influenced by attitudinal factors. To assess expected economic rewards resulting from the adoption of innovations, ten statements were applied. An example is: "*I expect that the implementation of the chosen agroecological practice for my farm will increase my profit*". To assess *expected* social rewards, namely how farmers perceived the implementation of sustainable innovations considering society's view toward the farm, four statements were used, such as: *"I expect that the implementation of the chosen agro-ecological practice will lead to my farm being more appreciated by society"*. To assess expected personal rewards, namely farmers' moral aspects of adopting sustainable practices, three statements were used. For example, one of these was: *"I expect that implementing the chosen agroecological practice will make me feel useful to society"*. All statements above mentioned were measured through a Likert scale from 1 (totally disagree) to 7 (totally agree) to collect farmers' level of agreement with each item. The three scales presented so far have been obtained from the work of Trujillo-Barrera et al. (2016). To assess farmers' risk relative attitude four items were used from Meraner and Finger (2019). We used the general statement "*I am willing to take more risks than my colleagues regarding*" followed by four elements related to four main risk sources that farmers are exposed to: production risks, marketing risks and prices; financial risks, and agriculture in general. Each respondent had to indicate their level of agreement on a scale of 1–5, where 1 meant 'totally disagree' and 5 meant 'totally agree'. Subsequently, winegrowers'

[1] Before starting the experimental survey, participants acknowledged an informed consent statement. The study was anonymous and no identifying information was collected at any stage of the experiment. The entire procedure was conducted in accordance with the key principles and ethical standards stated in the Declaration of Helsinki.

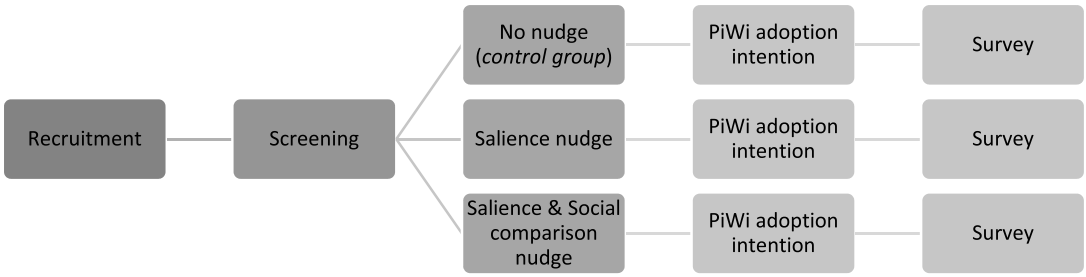

Fig. 1. Experimental steps.

perceived benefits from public incentives fostering innovation adoption were measured on a seven-point scale Likert scale. The final part of the questionnaire collected participants' sociodemographic information, such as age, sex at birth, and educational level. The entire procedure lasted approximately between 15 and 25 minutes.

3.2. Data analysis

Preliminary analyses were performed to test the effectiveness of randomization. The multivariate analysis of variance (ANOVA) showed no statistical difference between the three groups concerning the sociodemographic traits of winegrowers and farm size and turnover characteristics. To address our first research objective, a Kolmogorov-Smirnov equality of distributions test was employed to assess the significance of differences in the adoption likelihood distribution of PiWi varieties adoption among the experimental groups (Goldman and Kaplan, 2018). This test was chosen because the distribution of the dependent variable (PiWi adoption) deviated from a normal distribution. The values of the considered attitudinal scales (economic, social, and personal rewards, and risk attitude) were obtained through principal component factor analysis with varimax rotation. Subsequently, to further confirm the Kolmogorov-Smirnov test results and to examine the impact of drivers and barriers on the adoption of PiWi, a robust logistic regression was performed (Cameron and Trivedi, 2005). In addition to latent constructs identified through Principal Component Analysis (PCA), our analysis incorporates relevant interaction effects to account for moderation effects and observable characteristics of farmers that could influence the adoption of sustainable practices. Then we run a logistic regression expressed as follows:

$$Ppiwi_i = \beta_0 + \beta_1\ attitudinal\ measures + \beta_4 \text{Salience nudge} + \beta_5\ Social\ comparison + \ldots..\ e_i \quad (1)$$

in which $Ppiwi_i$ was equal to 1 when the probability of adoption is greater than the median value of the distribution and, 0 otherwise. This was done to follow the stream of the literature on the study of factors influencing the adoption of innovations in agriculture (Trujillo-Barrera et al., 2016; Ansah and Skevas, 2024). Since this is a hypothetical study and actual adoption could not be traced, the focus is on understanding the factors that influence a high or low probability of adoption. Therefore, the probability of adoption was divided into two groups based on the median value of 60%. This results in 58 cases with a high likelihood and 35 with a low likelihood in the salience group, and 47 cases with a high likelihood and 24 with a low likelihood in the coupled nudge group. Considering the total sample there were 142 cases with high probabilities of adoption and 102 cases with low probabilities.

We used the proxies for the rewards and risk attitude, derived from PCA, as regressors. Winegrower's sociodemographic characteristics were used as control variables. The perception of the benefits of the public incentives and holding organic certification were also included. To understand how the attitudinal characteristics influence the decision to adopt PiWi differently among subgroups, we conducted three logistic regressions: one for the total sample, one for the salience group, and one for the social comparison group.

Table 1
– Winegrowers' characteristics (N = 244).

Variables	Mean	S.D.
Age	49.44	13.4
Sex at birth (1 = men)	0.87	0.33
Level of education	3.55	1.16
Farm size (hectares)	23.7	29.46
Vineyard area (hectares)	12.02	11.38
Annual Turnover (€)	47.449	6.978
Organic certification (1 = yes)	0.37	0.484
Number of workers	2.01	1.34
Farm's experience	19.86	12.42
The usefulness of public incentives	5.24	1.81
Economic Rewards Scale	4.17	1.72
Social Rewards Scale	4.81	1.74
Personal Rewards Scale	4.59	1.71
Risk Attitude Scale	3.37	0.96

4. Results

4.1. Winegrowers' characteristics

Of the 249 responses collected, 5 were excluded due to incomplete data. Thus, the final convenience sample consisted of 244 winegrowers (Table 1). The average age of respondents was 49 years and almost 26% of the sample was under 40 years. Most respondents did not start and/or complete university studies (63%). Almost 90% of the farmers in our sample were men. The winegrowers surveyed indicated an average vineyard area per farm of 12 ha with an average annual turnover above forty-seven thousand euros. In the questionnaire, we also asked individuals' opinion about the public incentives introduced in Italy for the adoption of innovations. Among the 244 farms surveyed, 91 stated to hold an organic certification.

Regarding the innovation proposed, winegrowers, on average, indicated a 57.5% probability of adopting PiWi varieties in the next 5 years (Fig. 2). Specifically, the average likelihood of adoption reported by winegrowers over the next 5 years was 48.9% in the control group, 61.6% in the salience group, and 61.8% in the combined treatment group. As mentioned earlier, the likelihood of adoption was categorized into two groups: 1 for probabilities greater than or equal to 60% (the median value), and 0 otherwise.

Concerning the attitudinal variables, social rewards were most valued by respondents ($M = 4.81$), followed by personal ($M = 4.59$) and economic rewards ($M = 4.17$). The Cronbach's alphas for the three constructs were well above the lower limits of acceptability for newly developed scales (Hair et al., 2019). Winegrowers considered quite important receiving tax incentives for innovation adoption ($M = 5.24$) and expressed a relatively high-risk attitude ($M = 3.37$).

Regarding the attitudinal factors, since correlation analysis revealed strong relationships among the investigated constructs, we performed a Principal Component Factor Analysis (PCA), followed by an orthogonal varimax rotation of the loading matrix for the indicators considered. This process aimed to assess whether the indicators met two criteria: (*i*) loading more significantly on the assigned construct than on any other construct, and (*ii*) exposing loads of at least 0.70 on the designated construct, as recommended by Bagozzi et al. (1991) and subsequently adapted by Trujillo-Barrera et al. (2016). Indicators that failed to meet these criteria were subsequently excluded from further analysis. Three components that together explained 79.5% were extracted (Table 2). Factor 1 represents a proxy for economic rewards (ER), Factor 2 for social and personal rewards (SPR), and Factor 3 for risk attitude (RA).

This suggests that the analysis identified a common underlying factor that includes both social and personal rewards. In other words, the variation of observed variables relating to social rewards and personal rewards can be largely explained by a single factor, in contrast to distinct and separate factors for each. This result is indicative of a higher-order factor that captures the shared variance between social and personal rewards. This implies that there is a latent dimension that is common to both social and personal rewards, arguing that these two constructs are closely related or share common underlying mechanisms.

4.2. Nudge effectiveness

To evaluate the effectiveness of Nudge treatments, the Kolmogorov-Smirnov equality of distributions test was performed. The results show that both Salience Nudge and Salience coupled with Social Comparison Nudge were effective in increasing the likelihood of the adoption of PiWi varieties. By comparing distributions of the probability of adoption in salience treatment group and the probability of adoption in the control group we found a significant difference between these distributions (p-value < 0.05). Specifically, using salience nudge information increased the likelihood of PiWi varieties adoption by 12.7%, compared to the control group. Similarly, the distributions of control group and the treatment group (salience and social comparison nudge) exhibit significant differences (p-value < 0.1). The use of salience nudge coupled with social comparison nudge information led to a 12.9% increase in the likelihood of adopting PiWi varieties compared to the control group. Finally, by comparing the distributions of PiWi adoption between the two treatment groups no significant difference can be detected (p-value > 0.1). Overall, based on the results of the Kolmogorov-Smirnov test, adoption likelihood of PiWi varieties among winegrowers is increased by both types of nudge treatments (compared to the control group).

4.3. Adoption drivers

The second objective of the present study was to detect the impact of attitudinal factors, nudges, and contextual variables on the adoption of PiWi among winegrowers. Therefore, a robust logistic regression model was employed to examine the relationships between the variables under consideration. Odds ratios[2] are presented in Table 3. The first column (1) shows logistic regression results for the total sample. Model 2 (in column 2) corresponds to the salience group, and the third column (3) represents logistic regression outcomes on the coupled nudge group. Farmers' attitudes toward risk had a positive influence on the adoption of PiWi varieties for both the total sample and the salience nudge group. The higher the farmer's risk-taking attitude, the more likely they were to adopt PiWi varieties. Social and personal rewards did not influence adoption decisions in the salience group but had a positive effect on the likelihood of adoption for the coupled nudges group. Economic rewards did not show any effect in either the total sample or the two subgroups. Regarding the nudge impact, estimates confirm the significant effect of both interventions in increasing adoption

[2] An Odds ratio larger than 1 indicates that higher values on the independent variable make it more likely that participants will be among the high adoption likelihood category while an OR lower than 1 indicates that a higher value of independent variable increases the likelihood of participants to be in the lower category of adoption likelihood.

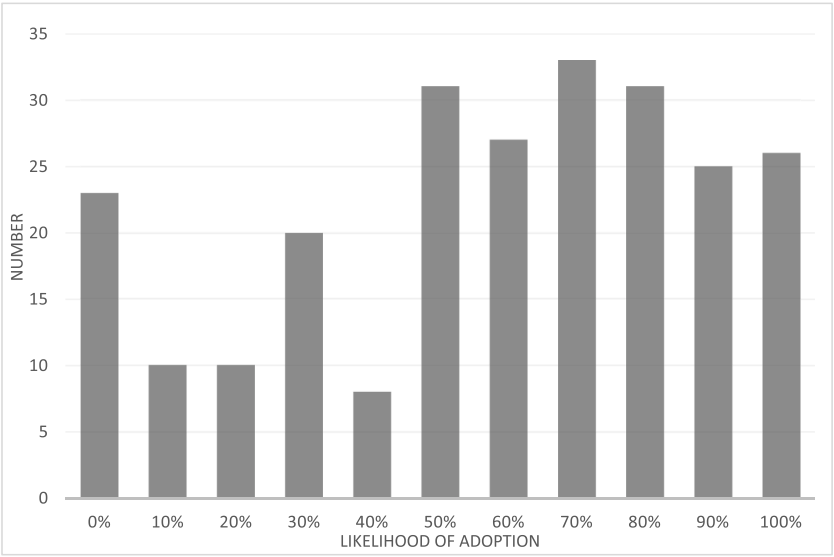

Fig. 2. Distribution of adoption likelihood (N = 244).

Table 2
Principal component analysis results (attitudinal characteristics).

	Factor 1	Factor 2	Factor 3
Economic Rewards (ER)			
I expect that the adoption of PiWi varieties for my farm will lead to:			
(1) An improvement in technical performance*	0.61	0.57	
(2) An improvement in financial performance*	0.72	0.52	
(3) More efficiency*	0.71	0.53	
(4) Labor savings	**0.81**		
(5) Lower cost price	**0.80**		
(6) Higher selling price	**0.75**		
(7) Higher productivity	**0.80**		
(8) Lower financial risk	**0.85**		
(9) Higher returns	**0.87**		
(10) More profits	**0.85**		
Social Rewards (SPR)			
I expect that the adoption of PiWi varieties will lead to my farm being:			
(1) More appreciated by society		**0.82**	
(2) Perceived as more desirable by society		**0.83**	
(3) Perceived as more proper by society		**0.84**	
(4) Perceived as more appropriate by society		**0.85**	
(5) Better at meeting the standards that people expect of agricultural entrepreneurs		**0.81**	
Personal Rewards (SPR)			
I expect that the adoption of PiWi varieties will lead me having feelings of:			
(1) Pride		**0.81**	
(2) Exhilaration*		0.60	
(3) Meaningfulness		**0.75**	
Risk Attitude (RA)			
I am willing to take more risks than my colleagues with respect to:			
Production risks			**0.82**
Marketing and pricing risks			**0.85**
Financial risks			**0.81**
Farming in general			**0.78**

Note: * = item dropped.

intentions. Odds ratios indicate that, among the attitudinal variables considered, social and personal rewards, along with risk attitude, are strong predictors for the adoption of PiWi varieties.

The link between a positive evaluation of the tax incentive for innovation in agriculture introduced in Italy and the likelihood of adoption of sustainable innovations turns out to be significantly true, but only for regression (1). Having an organic certification did

Table 3
Odds ratios of Robust Logistic Regression.

Variables	**(1)** Total Sample (N = 244)	**(2)**Salience group (n = 93)	**(3)**Coupled Nudge group (n = 71)
Social and personal Rewards (SPR)	1.351* *(0.210)*	1.022 *(0.319)*	3.726*** *(1.281)*
Economic Rewards (ER)	0.963 *(0.148)*	0.988 *(0.264)*	0.499 *(0.212)*
Risk Attitude (RA)	1.941*** *(0.270)*	2.112* *(0.664)*	1.743 *(0.676)*
Vineyard Area	0.972** *(0.018)*	0.967 *(0.029)*	0.880** *(0.055)*
Organic Certification	0.790 *(0.254)*	0.324* *(0.199)*	0.439 *(0.300)*
Farm's Experience	1.026* *(0.014)*	1.056** *(0.025)*	0.978 *(0.035)*
Annual turnover	1.000* *(0.000)*	1.000 *(0.000)*	1.000*** *(0.000)*
The usefulness of public incentives	1.248** *(0.136)*	1.156 *(0.228)*	1.312 (0.294)
Salience Nudge	1.887* *(0.660)*		
Coupled Nudge	2.157** *(0.842)*		
Control	Yes	Yes	Yes
Constant	*0.523 (0.525)*	*3.076 (5.481)*	*4.815 (9.739)*

Note: The dependent variable is a dummy for the adoption likelihood (1 for probabilities greater than or equal to 60% (the median value), and 0 otherwise). Standard errors are reported in parentheses. *, ** and *** indicate significance at $p < 0.10$, $p < 0.05$, and $p < 0.001$ respectively.

not influence the likelihood of adoption for either the total sample or the coupled nudge group. However, for the salience nudge group, the effect is significant and negative. The annual turnover positively affects adoption, although this is not the case for the salience group. The farm's experience appears to positively influence the adoption of PiWi varieties in models (1) and (2). The vineyard area has a significant and negative effects for the total sample and coupled nudge group. Observable variables such as winegrowers' sociodemographic (age, gender, education) were used as control variables.

Considering the total sample (1), 67.62% of the observations were accurately classified. This indicates that there might be other factors affecting winegrowers' adoption that were not considered in this study. Overall, the model has an acceptable goodness of fit (Pearson chi^2(230) = 233.17 p-value >0.05).

5. Discussion and conclusion

This study aimed to measure the impact of nudges on the likelihood of adoption of PiWi varieties among winegrowers and detect the core drivers and barriers in the likelihood of adoption.

First, PiWi varieties seem to be quite positively accepted by the convenience sample of Sicilian winemakers. Indeed, the overall sample likelihood of adoption in the upcoming 5 years stands at 57.5 percent. The propensity towards Piwi varieties may be fostered by the possibility of reducing the number of vineyard treatments and dropping losses due to attacks among others of downy mildew, powdery mildew, and botrytis, similar to what was found by Zachmann et al. (2023).

However, contrary to what was highlighted by Zachmann et al. (2023) on the effectiveness of nudge impact, in our study both treatments applied have been effective in encouraging the adoption of fungus-resistant varieties. In the salience group, the average likelihood of adoption indicated by winegrowers was 61.6%. Thus, the difference in average PiWi adoption likelihood between those who received salience nudge treatment and the control group was 12.7%. Giving information about the environmental consequences of the over-use of pesticides in vineyards may thus be an effective tool to reduce the application of chemical pesticides. Similar results are obtained by other studies. For example, Buchholz and Musshoff (2021) in a study involving 145 farmers in Germany found that salience nudge treatment is effective in encouraging pesticide reduction. Likewise, Michels et al. (2023) found an effective impact of salience in reducing the share of non-compliance with 14-day pre-harvest interval rule after the pesticide application. Current outcomes contrast with other studies applying salience nudge, where it has not been effective in encouraging the transition toward sustainable practices (Reddy et al., 2020; Pellegrin et al., 2018). Salience nudge was also used by Zachmann et al. (2023) to encourage the adoption of PiWi varieties in Switzerland. In addition, they found a boomerang-effect. In fact, considering the subpopulation of those who did not believe in the environmental benefits of these varieties, they found a 21-percentage point decrease in the expected area devoted to fungus-resistant varieties. Although the information in our study differed slightly from that used by colleagues, our results found the statistical efficacy of salience nudge in encouraging the adoption of PiWi varieties. This adds literature on the strong dependence on context informational treatments (Wu and Paluck, 2021).

Concerning the second treatment, in which the salience nudge was coupled with social comparison nudge, its effect is very similar to the single intervention. Indeed, the adoption likelihood of PiWi varieties in the combined treatment group was 61.9%. That is, a total effect value of 12.9% (Vs. control group), slightly greater than the salience nudge treatment alone. However, this difference was not statistically significant, as shown by the Kolmogorov-Smirnov test. It is noteworthy that other studies have reported a similar outcome. For example, Peth et al. (2018) explored the impact of nudges on farmers' adherence to the minimum-distance-to-water-rule by comparing a salience nudge with the same nudge coupled with social comparison information. Both nudges were effective in encouraging compliance with the rules, but the combination of salience nudge and social comparison nudge did not exhibit greater effectiveness than the use of the salience nudge alone (the probability of compliance with rules was 7.5% for the combined nudge and 8% for the salience nudge alone). The observed variations in effects may be attributed to the presence of the free-rider problem, as conceptualized by Olson (1965). Farmers may believe that if most of their peers adhere to the rules, their contribution to environmental pollution would be negligible. Consequently, they might perceive that their non-compliance is unlikely to result in significant negative externalities. The same may be contextualized in our result. The perception among farmers that most of their peers in the

wine-growing community are contributing to environmental conservation by reducing pesticide application through the adoption of PiWi varieties may not influence their own individual impact. This perception may influence some farmers to opt out of adopting these environmentally friendly innovations, assuming that their contribution might be relatively insignificant in the context of the collective efforts, as noted by Peth and Muβhoff (2020).

Unlike the findings of Trujillo-Barrera et al. (2016), our research revealed a positive effect of social and personal rewards associated with no effect of economic rewards on the adoption of PiWi grape varieties. Meaning that while the social and personal expectations are likely to be considered satisfying and may positively influence the decision to adopt PiWi varieties, the economic benefits are not immediately evident. Similarly, Mzoughi (2011) found that farmers who feel it is important to demonstrate their environmental commitment to others are more likely to adopt integrated pest management and organic farming (Mzoughi, 2011). Specifically, social variables reflect the farmer's desire to improve the social image and gain approval from peers and the community. Because PiWi varieties are innovations that align closely with environmental sustainability, farmers motivated by societal opinion are inclined to adopt these methods to strengthen their pro-environmental identity and conform to social norms that enhance sustainability. Our empirical evidence supports the idea that social approval and the desire to adhere to community standards significantly influence the adoption of sustainable agricultural practices.

The econometric model (3) showed a positive effect of the social and personal rewards, alongside a non-significant effect of the expectation of economic benefits on the adoption decision. Indeed, the expected social and personal rewards are the most influential factors given the magnitude of the odds ratio. This suggests that providing information about the adoption practices of peers in the same area triggered a significant response among farmers. It appears to evoke a greater sense of obligation, prompting farmers to perceive the adoption of sustainable practices not only as beneficial to their own interests but also as a conscientious decision aligned with societal values. This result demonstrates the power of combining a salience nudge with a social comparison nudge: by framing the innovation as the right choice to meet societal expectations and improve personal satisfaction, it shifts the focus from economic benefits to social and personal fulfilment.

However, we cannot neglect the importance of economic viability for producers. In our context, the grape-growing industry in Sicily has faced prolonged financial challenges, with many growers struggling to achieve sustainable turnovers. To boost the adoption of PiWi varieties, it is crucial to highlight the potential economic benefits. Indeed, farmers prioritize investments in sustainable technologies that enhance efficiency, performance, and profitability (Trujillo-Barrera et al., 2016), a trend not seen with PiWi varieties. For instance, economic rewards often take precedence over personal and social rewards when deciding to adopt sustainable practices. As found by Trujillo-Barrera et al. (2016) in the Dutch hog industry, adopters are primarily motivated by economic factors rather than social and personal ones, suggesting that economic considerations play a predominant role. As mentioned earlier, despite the lack of economic expectations, we observed a potential increase in the land devoted to these varieties over the next decade, similar to findings by Zachmann et al. (2023).

Contrary to the general trend observed by Iyer et al. (2020) among European farmers, our sample reported a higher average risk-taking tendency than their peers. The mean values derived from winegrowers' responses thus indicate a risk-taking disposition. This is confirmed by the results of the logit model. The greater the farmer's risk-taking attitude, the greater the likelihood of adoption of PiWi varieties. Other studies showed the important role of risk-taking behaviour in the adoption of innovations. Building upon the findings from Pavlis et al.'s (2016) study, it is evident that both economic and non-economic motives contribute to the deterrence of participation in Agri-Environmental Schemes (AES). Specifically, one significant deterrent identified is the perceived risk associated with the adoption of these schemes. The farmer's risk-related behavior is a deterrent to the adoption of an innovation, especially if that innovation is linked to uncertainty of outcome in terms of both economic and technical effectiveness (Rizzo et al., 2023; Uematsu and Ashok, 2011). Therefore, risk constitutes a barrier to the adoption of sustainable innovations (Trujillo-Barrera et al., 2016).

Finally, the model's results show that specific farm and farmer characteristics have a direct effect on the adoption decision, such as the vineyard area and farmers' experience in managing the farm. We found a negative effect of the farm's size on the adoption of PiWi varieties, in contrast to other studies. For instance, Läpple et al. (2015) detected a significant effect of farm size on the adoption of innovations, suggesting that the larger the farm, the higher the likelihood of adoption. However, our research applied a small, convenience sample and thus findings should be cautiously considered. Future studies should involve winegrowers operating in different geographical areas, also exploring the potential impacts of diverse cultural backgrounds and farmer practices.

In addition, we found a negative effect of managing an organic farm for those who received salience information. Farmers with organic certification may already have reduced pesticide use, meaning that the information about the negative consequences of excessive pesticide applications has less impact on them compared to individuals that do not possess such certification.

This study could have policy and research implications. From a policy point of view, policymakers should consider the introduction of framed messages in addition to traditional policy tools to encourage the adoption of sustainable innovations. Additionally, the outcomes of our research highlight that nudges' impact is also boosted by several attitudinal factors. Furthermore, policy instruments must take into consideration the relationship between risk attitudes and the decision to adopt sustainable practices. Consequently, economic incentives not only serve as catalysts for adoption but may also contribute to mitigating perceived risks associated with the adoption of sustainable innovation, rendering them more appealing to both individuals and businesses. In essence, the synergistic integration of instruments as nudge with traditional policy tools such as economic incentives emerge as a comprehensive and effective strategy for successfully fostering the ecological transition in agriculture. Findings disclose new, interesting research avenues. Scholars should thus consider social and personal motives when they explore the adoption of sustainable innovations in agriculture prompted by behavioral insights. However, the possibility of economic gains from adopting the innovation is certainly an important factor that farmers keep in mind when making decisions. Therefore, education and training tools should aim at increasing the awareness of the possible advantages (and potential disadvantages) of adopting a sustainable innovation.

Funding

Research funded by the European Union – NextGenerationEU. Project code 2022FMY5TR - Boosting Ecological Transition in the Agricultural Sector (BETAS).

CRediT authorship contribution statement

Francesco Vella: Writing – original draft, Investigation, Formal analysis, Data curation. **Giuseppina Migliore:** Writing – review & editing, Validation, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Giorgio Schifani:** Investigation. **Riccardo Vecchio:** Writing – review & editing, Validation, Supervision, Methodology, Investigation.

Declaration of competing interest

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

Appendix

Salience Nudge information (translated from Italian)

The agricultural sector contributes significantly to generating negative environmental impacts. Pesticides, including pesticides used to contrast vine diseases (fungicides and insecticides), kill beneficial insects, including bees, and accumulate in the food chain, compromising the survival of numerous animal species that feed on contaminated organisms.

Figure. Negative environmental impacts.

The European Union has set ambitious goals to minimize the negative impact of agriculture on the environment by introducing new ecological schemes in the new Common Agricultural Policy (CAP) that provide a significant stream of funding to promote environmentally friendly agriculture practices. Farmers will be required to minimize the use of synthetic chemicals, including plant protection products, and to approach more environmentally sustainable practices.

A recent survey of winegrowers showed that many of your colleagues in your area are already helping to reduce the negative impacts of viticulture on the environment by adopting innovative practices aimed at reducing the use of plant protection products in viticulture.

Data availability

Data will be made available on request.

References

Aguilera, R.V., Rupp, D.E., Williams, C.A., Ganapathi, J., 2007. Putting the S back in corporate social responsibility: a multilevel theory of social change in organizations. Acad. Manag. Rev. 32 (3), 836–863.
Aguinis, H., Glavas, A., 2012. What we know and don't know about corporate social responsibility: a review and research agenda. J. Manag. 38 (4), 932–968.
Ajzen, I., 1991. The Theory of planned behavior. Organizational Behavior and Human Decision Processes 50, 179–211.
Ajzen, I., Fishbein, M., 1980. Understanding Attitudes and Predicting Social Behavior. Prentice-Hall, Englewood-Cliff, NJ.
Ansah, M.O., Skevas, T., 2024. Adoption and intensity of use of personal protective equipment by agricultural pesticide handlers: empirical evidence from peruvian agriculture. J. Clean. Prod., 141433
Ansah, R.H., Sorooshian, S., 2019. Green economy: private sectors' response to climate change. Environ. Qual. Manag. 28 (3), 63–69.

Bagozzi, R.P., Yi, Y., Phillips, L.W., 1991. Assessing construct validity in organizational research. Adm. Sci. Q. 421–458.
Bavaresco, L., Squeri, C., 2022. Outlook on disease resistant grapevine varieties. In: BIO Web of Conferences, vol. 44. EDP Sciences, 06001.
Benartzi, S., Beshears, J., Milkman, K.L., Sunstein, C.R., Thaler, R.H., Shankar, M., Tucker-Ray, W., Congdon, W.J., Galing, S., 2017. Should governments invest more in nudging? Psychol. Sci. 28 (8), 1041–1055.
Blumenthal-Barby, J.S., Burroughs, H., 2012. Seeking better health care outcomes: the ethics of using the "nudge". Am. J. Bioeth. 12 (2), 1–10.
Boun My, K.B., Nguyen-Van, P., Pham, T.K.C., Stenger, A., Tiet, T., To-The, N., 2022. Drivers of organic farming: lab-in-the-field evidence of the role of social comparison and information nudge in networks in Vietnam. Ecol. Econ. 196, 107401.
Brown, Z.S., 2018. Voluntary programs to encourage refuges for pesticide resistance management: lessons from a quasi-experiment. Am. J. Agric. Econ. 100 (3), 844–867.
Buchholz, M., Musshoff, O., 2021. Tax or green nudge? An experimental analysis of pesticide policies in Germany. Eur. Rev. Agric. Econ. 48 (4), 940–982.
Byerly, H., D'Amato, A.W., Hagenbuch, S., Fisher, B., 2019. Social influence and forest habitat conservation: experimental evidence from Vermont's maple producers. Conservation Science and Practice 1 (9), 1–12.
Caicedo-Vargas, C., Pérez-Neira, D., Abad-González, J., Gallar, D., 2023. Agroecology as a means to improve energy metabolism and economic management in smallholder cocoa farmers in the Ecuadorian Amazon. Sustain. Prod. Consum. 41, 201–212.
Cameron, A.C., Trivedi, P.K., 2005. Microeconometrics: Methods and Applications. Cambridge university press.
Carvalho, F.P., 2017. Mining industry and sustainable development: time for change. Food Energy Secur. 6 (2), 61–77.
Casanova-Gascón, J., Ferrer-Martín, C., Bernad-Eustaquio, A., Elbaile-Mur, A., Ayuso-Rodríguez, J.M., Torres-Sánchez, S., et al., 2019. Behavior of vine varieties resistant to fungal diseases in the Somontano region. Agronomy 9 (11), 738.
Chabé-Ferret, S., Le Coent, P., Reynaud, A., Subervie, J., Lepercq, D., 2019. Can we nudge farmers into saving water? Evidence from a randomised experiment. Eur. Rev. Agric. Econ. 46 (3), 393–416.
Davis, F.D., 1993. User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. Int. J. Man Mach. Stud. 38 (3), 475–487.
Du, W., Yan, H., Feng, Z., Liu, G., Li, K., Peng, L., et al., 2024. Zoning for the sustainable development mode of global social-ecological systems: from the supply-production-demand perspective. Resour. Conserv. Recycl. 203, 107447.
Enticott, G., Little, R., 2022. Playing games with 'good farming': exploring the potential impact of disease control policies on farmers' cattle purchasing practices. J. Rural Stud. 92, 371–382.
European Commission, 2022. Towards CAP post 2027: evidence on nudging farmers to leverage more sustainable practices and behaviours. Available at: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2023-governance-01-3. (Accessed 8 January 2024).
Eurostat, 2024. Vineyards in the EU 2020. retrieved online at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Vineyards_in_the_EU_-_statistics.
Giorgi, F., Lionello, P., 2008. Climate change projections for the Mediterranean region. Global Planet. Change 63 (2–3), 90–104.
Goldman, M., Kaplan, D.M., 2018. Comparing distributions by multiple testing across quantiles or CDF values. J. Econom. 206 (1), 143–166.
Hair, J.F., Risher, J.J., Sarstedt, M., Ringle, C.M., 2019. When to use and how to report the results of PLS-SEM. European Business Review 31 (1), 2–24.
Huirne, R.B.M., 2003. Strategy and risk in farming. NJAS - Wageningen J. Life Sci. 50 (2), 249–259.
ISMEA, 2022. L'Italia del vino nel 2021- scheda di settore. Retrieved online at. https://www.ismeamercati.it/flex/files/1/f/d/D.244608742167ac51f977/SchedaVino_2022_04.pdf.
ISTAT, 2022. 7° Censimento Generale dell'Agricoltura. Istat, Roma. Available at: https://www.istat.it/it/censimenti/agricoltura/7-censimento-generale. (Accessed 7 November 2023).
Iyer, P., Bozzola, M., Hirsch, S., Meraner, M., Finger, R., 2020. Measuring farmer risk preferences in Europe: a systematic review. J. Agric. Econ. 71 (1), 3–26.
Keshavarz, M., Sharafi, H., 2023. Scaling up climate-smart regenerative agriculture for the restoration of degraded agroecosystems in developing countries. Sustain. Prod. Consum. 38, 159–173.
Langen, N., Ohlhausen, P., Steinmeier, F., Friedrich, S., Engelmann, T., Speck, M., et al., 2022. Nudges for more sustainable food choices in the out-of-home catering sector applied in real-world labs. Resour. Conserv. Recycl. 180, 106167.
Läpple, D., Renwick, A., Thorne, F., 2015. Measuring and understanding the drivers of agricultural innovation: evidence from Ireland. Food Pol. 51, 1–8.
Lorenz, D.H., Eichhorn, K.W., Bleiholder, H., Klose, R., Meier, U., Weber, E., 1995. Phenological growth stages of the grapevine (Vitis vinifera L. ssp. vinifera)—codes and descriptions according to the extended BBCH scale. Aust. J. Grape Wine Res. 1, 91–103.
Meraner, M., Finger, R., 2019. Risk perceptions, preferences and management strategies: evidence from a case study using German livestock farmers. J. Risk Res. 22 (1), 110–135.
Meuwissen, M.P., Huirne, R.B.M., Hardaker, J.B., 2001. Risk and risk management: an empirical analysis of Dutch livestock farmers. Livest. Prod. Sci. 69 (1), 43–53.
Michels, M., Luo, H., von Ahlefeld, P.J.W., Mußhoff, O., 2023. Compliance with pre-harvest interval rules in apple production—a comparative analysis of green nudges among fruit growers and agricultural students in Germany. Journal of Behavioral and Experimental Economics 102, 101963.
Migliore, G., Zinnanti, C., Schimmenti, E., Schifani, G., Di Franco, C.P., Borsellino, V., Asciuto, A., 2019. A Ricardian analysis of the impact of climate change on permanent crops in a Mediterranean region. New Medit 18 (1), 41–51.
Mohr, S., Kühl, R., 2021. Acceptance of artificial intelligence in German agriculture: an application of the technology acceptance model and the theory of planned behavior. Precis. Agric. 22 (6), 1816–1844.
Mzoughi, N., 2011. Farmers adoption of integrated crop protection and organic farming: Do moral and social concerns matter? Ecological Economics 70 (8), 1536–1545.
Nicolopoulou-Stamati, P., Maipas, S., Kotampasi, C., Stamatis, P., Hens, L., 2016. Chemical pesticides and human health: the urgent need for a new concept in agriculture. Front. Public Health 4, 148.
OIV, 2022. State of the world vine and wine sector in 2022. Retrieved online at: https://www.oiv.int/sites/default/files/documents/OIV_State_of_the_world_Vine_and_Wine_sector_in_2022_2.pdf.
Olson, M., 1965. The Logic of Collective Action: Public Goods and the Theory of Groups. Harvard University Press, Cambridge, MA.
Pavlis, E.S., Terkenli, T.S., Kristensen, S.B., Busck, A.G., Cosor, G.L., 2016. Patterns of agri-environmental scheme participation in Europe: indicative trends from selected case studies. Land Use Pol. 57, 800–812.
Pedneault, K., Provost, C., 2016. Fungus resistant grape varieties as a suitable alternative for organic wine production: benefits, limits, and challenges. Sci. Hortic. 208, 57–77.
Pellegrin, C., Grolleau, G., Mzoughi, N., Napoleone, C., 2018. Does the identifiable victim effect matter for plants? Results from a quasi-experimental survey of French farmers. Ecol. Econ. 151, 106–113.
Pertot, I., Caffi, T., Rossi, V., Mugnai, L., Hoffmann, C., Grando, M.S., et al., 2017. A critical review of plant protection tools for reducing pesticide use on grapevine and new perspectives for the implementation of IPM in viticulture. Crop Protect. 97, 70–84.
Peshin, R., Bano, F., Kumar, R., 2019. Diffusion and adoption: factors impacting adoption of sustainable agricultural practices. Natural Resource Management: Ecological Perspectives, pp. 235–253.
Peshin, R., Vasanthakumar, J., Kalra, R., 2009. Diffusion of Innovation Theory and Integrated Pest Management. *Integrated Pest Management: Dissemination and Impact*, vol. 2, pp. 1–29.
Peth, D., Mußhoff, O., 2020. Comparing compliance behaviour of students and farmers. An extra-laboratory experiment in the context of agri-environmental nudges in Germany. J. Agric. Econ. 71 (2), 601–615.
Peth, D., Mußhoff, O., Funke, K., Hirschauer, N., 2018. Nudging farmers to comply with water protection rules–experimental evidence from Germany. Ecol. Econ. 152, 310–321.
Prelez, J., Wang, F., Shreedhar, G., 2023. For the love of money and the planet: experimental evidence on co-benefits framing and food waste reduction intentions. Resour. Conserv. Recycl. 192, 106904.

Rainatto, G.M., de Sousa Jabbour, A.B.L., Machado, M.C., Jabbour, C.J.C., Tiwari, S., 2024. How can companies better engage consumers in the transition towards circularity? Case studies on the role of the marketing mix and nudges. J. Clean. Prod. 434, 139779.
Reddy, S.M., Wardropper, C., Weigel, C., Masuda, Y.J., Harden, S., Ranjan, P., Getson, J.M., Esman, L.A., Ferraro, P., Prokopy, L., 2020. Conservation behavior and effects of economic and environmental message frames. Conservation Letters 13 (6), 1–5.
Rizzo, G., Migliore, G., Schifani, G., Vecchio, R., 2023. Key factors influencing farmers' adoption of sustainable innovations: a systematic literature review and research agenda. Organic Agriculture 1–28.
Rogers, E.M., 2003. Diffusion of Innovations, fifth ed. Free Press, New York.
Santos, J.A., Fraga, H., Malheiro, A.C., Moutinho-Pereira, J., Dinis, L.T., Correia, C., et al., 2020. A review of the potential climate change impacts and adaptation options for European viticulture. Appl. Sci. 10 (9), 3092.
Trujillo-Barrera, A., Pennings, J.M., Hofenk, D., 2016. Understanding producers' motives for adopting sustainable practices: the role of expected rewards, risk perception and risk tolerance. Eur. Rev. Agric. Econ. 43 (3), 359–382.
Uematsu, H., Ashok, M.K., 2011. Learning by Doing, Risk Aversion and Use of Risk Management Strategies. No. 321-2016-10820).
Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F. D, 2003. User acceptance of information technology: Toward a unified view. MIS quarterly 27 (3), 425–478.
von Kameke, C., Fischer, D., 2018. Preventing household food waste via nudging: an exploration of 801 consumer perceptions. J. Clean. Prod. 184, 32–40.
Wu, S.J., Paluck, E.L., 2021. Designing nudges for the context: golden coin decals nudge workplace behavior in China. Organ. Behav. Hum. Decis. Process. 163, 43–50.
Xu, Z., Zheng, Y., Wu, Y., 2024. Paving the way for sustainable agriculture: an analysis of evolution and driving forces of methane emissions reduction in China. Resour. Conserv. Recycl. 202, 107392.
Zachmann, L., McCallum, C., Finger, R., 2023. Nudging farmers towards low-pesticide practices: evidence from a randomized experiment in viticulture. Journal of the Agricultural and Applied Economics Association 2 (3), 497–514.
Zeweld, W., Van Huylenbroeck, G., Tesfay, G., Speelman, S., 2017. Smallholder farmers' behavioural intentions towards sustainable agricultural practices. J. Environ. Manag. 187, 71–81.