Compliance with pre-harvest interval rules in apple production—A comparative analysis of green nudges among fruit growers and agricultural students in Germany

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ABSTRACT

Using an incentivized single-player multi-period business management game in which the participants have to manage a virtual apple farm as an experimental device, this study examines how nudges can improve compliance with regard to the 14-day pre-harvest interval rule after the pesticide application. Two different samples were examined, namely German fruit growers and agricultural students. Two different green nudge treatments were investigated: A nudge with facts and pictures which imply environmental and health damages that are presumably caused by breaching the 14-day pre-harvest interval rule, and a nudge with an additional social comparison suggesting that the majority of fruit growers in the same region comply with the rule. The core result of the study is that nudging has a preventive effect and reduces participants' non-compliance behavior in the business management game. The results are of interest to (agricultural) policy makers dealing with regulatory strategies in the context of pre-harvest intervals in apple production, as it is widely documented that nudging is an effective low-cost supplement to controls. Furthermore, the results are of interest for further research in the field of (experimental) economics and nudging, as we provide novel insights into the application of nudges.

1. Introduction

Nudging is an instrument that tries to steer the decisions of a target group in a certain direction by modelling the decision architecture (Thaler & Sunstein, 2008). This behavioral economic instrument works without restricting the freedom of decisions and is characterized by relatively low financial costs (Michalek et al., 2016). In a direct comparison of nudges with other traditional regulatory measures, it was found that correct use of nudges can be a more effective method (Galle, 2013; Ouvrard & Spaeter, 2016). Thus, nudging can be considered as an extension and support to existing policy instruments in order to achieve desired goals by altering individual behavior without directly restricting or forbidding any options.

Ex-ante policy impact analysis would assist in the design and implementation of effective nudge treatments when scaling up. In comparison to ex-post analysis, ex-ante policy impact analysis is usually performed in a controlled and self-created environment, so that the costs of conducting several times under the same conditions are low (Patel & Fiet, 2010). Economic experiments in general and business management games in particular are promising tools for an ex-ante policy impact analysis (Mußhoff & Hirschauer, 2014). Business management games have a high internal validity because their environment is largely protected from external influences. Moreover, business management games can have advantages over classical economic experiments if they take place in a setting, which is familiar to the participants. Like economic experiments in general, the external validity and participants' performance in the business management games can be strengthened by financial incentives (Hertwig & Ortmann, 2001; Mußhoff & Hirschauer, 2014).

The non-compliance with agri-environmental regulations can lead to negative effects on the environment and human well-being (Pretty et al., 2001). Furthermore, implementing an ineffective policy measure can result in opposing effects and high costs. As a result, green nudges in the context of environmental policies, agricultural production and its externalities have gained the interest of researchers (e.g. Schubert et al., 2017). Recently, Buchholz & Mußhoff (2021) investigated the effect of a tax and a green nudge on the pesticide application in the context of winter wheat and silage maize cultivation by German arable farmers using a business management game. Besides other results, this study showed that the green nudge can effectively reduce pesticide

applications. In addition, and according to literature, it can be expected that a nudge with an additional social comparison is more effective than a pure informational nudge (e.g. Schultz et al., 2007; Bartke et al., 2017). For instance, Kuhfuss et al. (2016a) showed how successful a social nudge can be in influencing decisions of French wine growers. They showed that the additional information available on the involvement of other farmers in agri-environmental measures leads to the fact that an individual farmer is also more willing to participate in agri-environmental measures. Nevertheless, green nudges with and without a social comparison have never been studied in the context of compliance with pre-harvest intervals (waiting periods) for pesticides in agriculture, particularly with regard to the compliance behavior of fruit growers. The pre-harvest interval is the minimum time between the last application of a crop protection product and the harvest or the earliest possible use of the treated crop. Fruit farmers' income is strongly influenced on the one side by the fact that they receive a penalty for violations of pre-harvest intervals after the control. On the other side, an earlier harvest with a possible higher product price is a strong monetary incentive to not adhere to the pre-harvest intervals. These pre-harvest intervals are controlled by competent authorities since they are of great importance for consumer protection. However, these controls might not be very effective and at the same time costly (Pimentel et al., 1992). In this context, green nudges could prove to be a low-cost and effective complement to controls (e.g. Ferrari et al., 2019).

The objectives of this study are therefore the following: First, this study investigates the effect of green nudges in the context of compliance with pre-harvest intervals for pesticides in pomiculture. Second, our study investigates whether the effectiveness of green nudges with and without a social comparison differ in influencing compliance with pre-harvest intervals in fruit growing. In economic experiments, students are often recruited because of their low opportunity costs and high availability, which leads to the question if agriculture students can be used to approximate farmers' behavior in economic experiments (e.g. Gruener et al., 2022). Hence and third, this study deals with the extent to which the responsiveness to green nudges of agricultural students is comparable with that of fruit growers as a specific group of farmers in the context of adherence to pre-harvest intervals in apple production.

To the best of our knowledge, no studies have addressed these research questions. For answering the research questions, a multi-period single-player business management game was developed and carried out in which participants take the role of decision makers and decide on the date of pesticide applications and the date of harvesting in apple production. In the context of this decision-making process, the effect of the nudges is investigated. In treatment group A, a nudge includes information with pictures (Kahnemann, 2011) showing the positive effects of compliance with pre-harvest intervals in pomiculture, and in treatment group B, we designed another nudge with an additional social comparison (e.g. Bartke et al., 2017), which gives the participants a clear picture showing that other fruit growers in their region comply with pre-harvest intervals. This is of potential interest for policy makers to increase adherence to statutory regulations in food production in a more targeted and effective manner, ultimately leading to food safety. In addition, the effects of the green nudges are studied with agricultural students and fruit growers. The results of the comparability of both groups in terms of responsiveness to the green nudges could provide insights for other ex-ante policy impact analysis and (experimental) studies regarding fruit growing and the use of green nudges. Furthermore, the effect of green nudges with and without a social comparison is investigated in the context of adherence to pre-harvest intervals for pesticide application in specific.

The remainder of this paper is structured as follows: The background and hypotheses generation are presented in Section 2. Section 3 describes the design of the experiment. In Section 4, the results are presented, followed by a brief discussion in Section 5. The paper ends in Section 6 with the conclusion.

2. Background and hypotheses generation

Over the last years, growing criticism of food production by consumers and other stakeholders has shown how society's awareness has changed (Heyder & Theuvsen, 2008). One example is the use of pesticides in agriculture and their residues in food. Residues have fallen steadily in recent decades (BVL, 2021a), yet they remain present. The German national report "Pesticide residues in food" published by the Federal Office of Consumer Protection and Food Safety (BVL) in 2019 shows that residues were found in 65.6% of the food group "fruit, vegetables and other plant foods" in Germany. Likewise, samples with residues in excess of the acute reference dose (ARfD) and the legal maximum levels were detected. Some of these substances are suspected of having carcinogenic or mutagenic effects. Moreover, the number of complaints about food products exceeding the maximum residue levels are also reported in the German national reporting BVL. Apples still have a comparatively low residue level with a total of 0.3% complaints compared to other fruits and vegetables (BVL, 2021a). However, based on the German average annual apple consumption of 21.9 kg in 2019/20 and the average weight of an apple being 112 g, each consumer eats on average 1.6 apples per year in which the maximum residue level is exceeded (BVL 2003; BMEL, 2021). Multiple residues are not considered. In principle, this does not mean that the consumer is now directly at risk of toxicity, but health risks are clearly evident (Lundehn & Bentlage, 1984).

There are different ways to prevent residues in agricultural products. The Federal Office of Consumer Protection and Food Safety suggests measures such as setting pre-harvest intervals (BVL, 2021b). However, Lundehn & Bentlage (1984) argue that compliance with the statutory maximum quantities laid down is only possible if users of pesticides comply with pre-harvest intervals. These pre-harvest intervals are controlled by competent authorities, which might be costly and ineffective (Pimentel et al., 1992). Against these backgrounds, green nudges could prove to be a low-cost, effective complement to controls (e.g. Ferrari et al., 2019) and serve as a preventive instrument to increase compliance. To successfully implement a green nudge, there is a need for deeper knowledge about fruit growers' compliance behavior in this context. It should be stressed that knowledge about the effects of specific nudges under certain conditions cannot be easily transferred to another situation or environment. To be more precise, the effectiveness of different nudges depends on their communication to the recipients, the structure of the nudges as well as the perception of the individual recipients (Sunstein, 2017; Bruns et al. 2018). Hence, the effectiveness of different nudges has to be evaluated individually in an explicit context to find out possible counterproductive behavior in the form of reactance in response to the nudges. To date, it is unknown if green nudges work in the context of pesticide use in apple production and how this can ensure fruit growers adhere to mandatory pre-harvest intervals. Hence, the following hypothesis is to be tested:

H1: A green nudge is a suitable instrument for reducing pre-harvest interval violations in fruit growing

Adding a social comparison to a nudge is expected to increase the effectiveness of the purely informational nudge (e.g. Bartke et al., 2017), which can be explained by the fact that the behavior of others and peers in the same group influences an individual's behavior (e.g. Falk et al., 2010). Czap et al. (2015) showed that informing a farmer about the environmental consequences of their behavior on other farmers decreases farmers' environmentally damaging behavior. Kuhfuss et al. (2016a) showed that the information that other French wine growers participate in agri-environmental measures leads to the fact that an individual farmer is also more willing to participate in agri-environmental measures. However, in contrast to the authors' expectations and the cited literature, adding a social comparison to a green nudge was found to be no more effective than the purely informational nudge in improving compliance behavior with water protection rules by Peth et al. (2018). Similarly, Chabé-Ferret et al. (2019) showed only minor

treatment effects of social nudges in the context of sustainable water use among French farmers. Most recently, Massfeller et al. (2022) could not detect an effect of a social nudge on farmers' willingness to participate in agri-environmental schemes. Despite the mixed results in the literature, we derive the following hypothesis:

H2: A green nudge in combination with a social comparison is more effective than a green nudge without a social comparison to reduce pre-harvest interval violations in fruit growing

A number of studies have analyzed and reviewed the behavioral differences between students and the real group of social interest in a variety of economic experiments (e.g. Fréchette, 2015; Rosch et al., 2021; Weigel et al., 2021; Gruener et al., 2022). Some of these studies reveal that students and non-students tend to perform similarly, while others show that they behave differently (Belot et al., 2015; Frigau et al., 2019). In (agricultural) economics research, economic experiments have been conducted with students (e.g. Ferré et al., 2017; Andersen et al., 2010; Buchholz et al., 2021) as well as with farmers (e.g. Kuhfuss et al., 2016a, b; Hermann et al., 2017; Peth et al., 2018), but only a few studies have compared behavioral differences between students and professional farmers in the same experiment (e.g. Waichman & Ness, 2012; Suter & Vossler, 2013; Gruener et al., 2022)[1]. Few studies have focused on the effects of nudging on both students and farmers. To the best of our knowledge, the only comparable study was conducted by Peth and Mußhoff (2020), which deals with the effect of green nudges on German agricultural students and farmers in the context of compliance behavior with regard to water protection rules. The results showed that both groups of participants (professional farmers and agricultural students) were receptive to the nudges regarding the compliance behavior of water protection rules. However, it is not known if agricultural students can also be used as a meaningful convenience group for fruit growers as a specific form of farmer. Moreover, it has not been investigated yet, whether and in which direction the responsiveness to green nudges of agricultural students is comparable to that of fruit growers in the context of adherence to pre-harvest intervals after pesticide application in apple production. Hence, the following hypothesis is derived:

H3: Agricultural students' responsiveness to the nudges in terms of directing the behavior in the desired way is comparable with that of the fruit growers

3. Experimental design

The online experiment consists of three parts. In the first part, socio-demographic characteristics of the participants were collected via a questionnaire. In the second part, compliance behavior in the context of pesticide use in apple production was collected via an incentivized one-player multi-period business management game. In the last part, participants had to self-rate their law-abiding attitude in a general sense on a Likert scale from zero to ten. Furthermore, participants' risk attitude was assessed by an incentivized Holt-and-Laury lottery (Holt & Laury, 2002). A translated English version of the business management game instructions, which were provided to participants in German, can be found in the Appendix. The following subsections focus on explaining the business management game to ensure the comprehensibility of the main part of the study.

3.1. Assessment of non-compliant behavior

In the business management game, the participants had to manage a

virtual apple farm over six production periods (six rounds). In the simulation, the apple farm covered 6 hectares, each with 13,500 apple trees. On every two hectares, one of the varieties Jonagold, Braeburn and Elstar[2] was cultivated, which on the one hand increases the realism of the business management game, and on the other hand contributes to increase the fun of the business management game. The participants were asked to first decide when to apply pesticides and then when to harvest for each apple variety in each period. Thus, the difference between these two dates indicates whether they complied with the pre-harvest intervals. A period starts with the date of the last pesticide application of the first ripe variety as decided by the participants. For this decision, the participants had information on the estimated harvest date, the expected weather for the next 14 days, reasonable advice regarding the best date for the pesticide use and a reminder of the 14-day pre-harvest interval (see Appendix). After making the decision on the date of the pesticide application and some days passed in the business management game, the participants had to determine the harvest time. For this decision, the participants had to consider the pre-harvest interval. In order to decide when the next possible best date for harvesting would be, the following information is important and was provided: The price trend for the respective variety, the estimated harvest yield and the weather forecast. However, the latest advice on harvest date might be earlier than the previously estimated harvest date and less than the 14-day pre-harvest interval. At the same time, a key feature of the game is that the selling price of apples decreases constantly during each production period. Therefore, the longer the waiting time, the lower the price of apples the players receive and ultimately the lower their payoff. However, although not sticking to the pre-harvest intervals could lead to higher returns and a possible higher payoff for participants, this can result in a fine of €1200 per hectare and a complete reduction of subsidies to the value of €300 per hectare[3] they received in each period. In reality, it is reported that 1% of the farms would be controlled (BMEL, 2019a). Therefore, participants had the impression that if they wanted to increase revenues in this way, they were taking a risk. If participants stated a pre-harvest interval shorter than 14 days, this was recorded as non-compliance. After the participants selected the harvest date, the explained process is repeated for the remaining two varieties, which ripen later. At this point, the production period for the respective season is over. To sum it up, all participants had to make six decisions in each period (one date for pesticide application and one date for harvest for each of the three apple varieties). After fully completing one period (one round), the decision situations were repeated five times for the remaining five periods.

3.2. Experimental treatments

Participants were randomly assigned to one of three groups at the beginning of the business management game. In the first three periods, the framework remained the same. In the last three periods, conditions only remained the same for the control group. The other two groups, A and B, received different nudge messages according to their assigned treatments. Participants of group A were provided with information about the consequences of non-compliance with the pre-harvest interval rule:

"*Many scientists warn against the unintentional intake of pesticides through the consumption of fruit and vegetables. Some pesticides are suspected of triggering diseases such as Parkinson's, cancer and allergies.*

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[1] For an overview and discussion on the topic of students and farmers in economic experiments see Cason and Wu (2019) and Rosch et al. (2021).

[2] The three apple varieties were chosen to reflect the reality as closely as possible, as most fruit growers have more than one variety in their orchards. However, in the following analysis we do not explicitly distinguish between the decisions made for the different varieties.

[3] The subsidies of €300 per hectare are intended to imitate payments received in reality, such as EU agricultural subsidies.

Pregnant women are particularly affected, as the risk of miscarriage increases or new-borns can be born with malformations. […] One reason for these high residues is a violation of the prescribed withdrawal period when a pesticide is last used before harvesting. Only if this pre-harvest interval is observed can it be guaranteed that no increased residues are present at the time of harvesting and that the limit values are not exceeded.

Help to protect the health of consumers"

This information was supported by pictures of a crying baby and the pesticide application in an apple plantation. In group B, participants received the same informational nudge as in group A, but with an additional social comparison. The social comparison is framed personally, namely we stated in nudge B that[4]:

"*An investigation has shown that apple producers especially in your region comply with the prescribed pre-harvest interval. Your professional colleagues on the neighboring apple plantations also help to protect consumers from risks by observing the pre-harvest interval.*

You too can help to protect the health of consumers".

3.3. Incentives

In experimental economics, researchers often provide participants with financial incentives to encourage thoughtful decisions (e.g. Guala, 2005; Voslinsky & Ofer, 2021). In our experiment, participants were informed about a participation fee and additional prize money for subsequent experimental tasks at the beginning of the survey. Detailed information about the chances of winning and how the prizes were determined was provided at the beginning of the business management game and the Holt-and-Laury lottery task, respectively.

Participation in the experiment took about 30 min. To give participants an incentive to fully complete the experiment, the agricultural students were each reimbursed with an Amazon voucher worth €10 after completing the survey. Fruit growers were each given an Amazon voucher worth €30 after completing the survey, as this was done to compensate fruit growers with a higher reward for the higher opportunity cost. Other monetary rewards were the same for both agricultural students and fruit growers. In the business management game, participants had a 10% chance of being drawn at random and those selected receiving €100 for every €200,000 in total profits earned in the business management game. This incentive is intended to stimulate participants to show their true behavioral preferences because non-compliance with the pre-harvest interval rule is a socially undesirable behavior and if no incentive is provided, participants may hide their true preferences and demonstrate socially desirable behavior (Milfont, 2009; Norwood & Lusk, 2011). In the lottery task, in which participants were asked to choose between option A and option B for each of the ten paired lotteries, every fifteen participants were selected at random to win an additional payoff. Following the random selection of the winners, one of the ten lottery choices would be randomly chosen as the payoff via a ten-sided die. The die would be thrown again to determine the exact earnings of the selected lottery. Depending on the design of the Holt-and-Laury lottery, it was possible to win between €1 and €38.50.

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[4] It should be noted that this information was communicated to everyone in group B. The readers should keep in mind that not all fruit growers/agricultural students were playing the game at the same point in time. However, a deception described by Cooper (2014) can be ruled out since it was not stated that other participants in the game or in the region behave in this way at that moment. Furthermore, the statement is also closely related to reality since farmers indicate in exchange among colleagues that they comply with the pre-harvest interval, although they may not have. Farmers are not able to verify this information provided by their colleagues.

4. Results

4.1. Sample characteristics and attitudes

The survey was conducted online from May until September 2018 with a sample of German fruit growers and in November and December 2016 with a sample of German agricultural students. To ensure that only genuine fruit growers participated in the survey, an e-mail invitation to the survey was sent out through fruit grower organizations or their public business e-mail addresses. Agricultural students were recruited among the undergraduate agricultural students at the University of Goettingen and the University of Halle-Wittenberg. For the agricultural students, it was not a pre-condition to be related in any way to fruit growing. In total, complete data were recorded from 215 participants (67 fruit growers[5] and 148 agricultural students). The survey and the multi-period single-player business management game did not have to be completed parallelly by all participants. Fruit growers and agricultural students could start at their preferred time during the survey period mentioned above. The sample characteristics are summarized in Table 1.

The fruit growers in the sample are on average 38.48 years old and the agricultural students are on average 21.70 years old. One of the most noticeable differences between the two subject groups is the share of female participants. In the agricultural student sample, 50% are female whereas only 25% of the fruit growers sample are female, reflecting the low share of female farm managers in Germany (in 2013, < 15 % of German farms were managed by women (DBV, 2019)). There is also a mentionable difference in the share of participants with association membership. 70% of the fruit growers are members of an association whereas only 23% of the agricultural students have a membership. The high membership share among fruit growers is probably due to the fact that German fruit growers most often organize themselves in specific sector associations, for instance Bundesvereinigung der Erzeugerorganisation Obst und Gemüse e. V., which represent the interests of fruit growers. The results of the Holt-and-Laury lottery task and the self-assessed law-abiding behaviors are also shown in Table 1. Although there are differences in both risk attitude and law-abidance between fruit growers and agricultural students, these differences are not statistically significant, as shown by Mann-Whitney-U tests conducted ($p = 0.970$ and $p = 0.140$, respectively). On average, fruit growers and agricultural students are slightly risk averse as well as rather law-abiding. An overview of the descriptive statistics of the three experimental groups can be found in Table A in the Appendix. Overall, all these characteristics do not differ statistically significantly between the control and two treatment groups.

The concrete findings of Table 1 can be summarized as follows: As expected, there are statistically significant differences in socio-demographic characteristics between agricultural students and fruit growers, such as age, educational level, the share of female participants and the share of participants with an association membership. However, there are no statistically significant differences between agricultural students and fruit growers regarding their risk attitudes and law-abidance.

4.2. Compliance behavior

The behavior of the experimental subjects regarding the minimum-waiting-period rule was assessed both categorically (compliance vs. non-compliance) and metrically (difference in the number of days between the 14-day pre-harvest interval and the self-determined waiting days). Fig. 1 shows the average percentage share of non-compliance for agricultural students and fruit growers in each period and group

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[5] 67 fruit growers satisfy Bartlett et al.'s (2001) minimum sample size estimation with a population size of 7617 German fruit growers (DESTATIS, 2017), an applied margin of error of 10% and a confidence interval of 90%.

Table 1

Summary statistics of participants ($n = 215$).

Variable	Description	Agricultural students (n=148)		Fruit growers (n=67)		Statistical significance of differences
		Mean	SD	Mean	SD	
Demographic Variables						
Age	Age in years	21.70	3.47	38.48	12.93	$p < 0.001$ [c]
Agricultural training	1, if the participant completed an agricultural training; 0 otherwise	0.22	-	0.70	-	$p < 0.001$ [d]
Association membership	1, if the participant is a member of an agricultural association; 0 otherwise	0.23	-	0.70	-	$p < 0.001$ [d]
Gender	1, if the participant is female; 0 otherwise	0.50	-	0.25	-	$p = 0.001$ [d]
Household size	Total number of household member	3.17	1.72	4.03	3.33	$p = 0.011$ [c]
University degree	1, if the participant holds a university degree; 0 otherwise [e]	0.09	-	0.55	-	$p < 0.001$ [d]
Attitudes						
Law abidance[b]		6.86	2.19	7.30	2.24	$p = 0.140$ [c]
	Rather law-abiding	0.68	-	0.82	-	
	Neither nor law-abiding	0.19	-	0.07	-	
	Rather not law-abiding	0.14	-	0.10	-	
Risk attitude[a]		5.01	1.78	5.06	1.69	$p = 0.970$ [c]
	Risk averse	0.55	-	0.55	-	
	Risk neutral	0.32	-	0.39	-	
	Risk seeking	0.14	-	0.06	-	

[a] Holt-and-Laury (HLL) values; $0 - 3$ = risk-seeking, 4 = risk neutral, $5 - 10$ = risk averse. The risk aversion classification is based on the number of safe lottery choices (Lottery A).

[b] Law abidance self-assessment scale; $0 - 4$ = rather not law-abiding, 5 = neither nor law-abiding, $6 - 10$ = rather law-abiding.

[c] Mann-Whitney U test.

[d] Chi-squared test.

[e] Including bachelor degree from university of applied sciences

SD = Standard deviation.

graphically and tabularly. If a decision on waiting days violates the rule, this decision is considered non-compliance at this point. For instance, in the control group of agricultural students ($n = 48$), 144 decisions (48*3)[6] are considered in each period. In period 1, an average of 55% of the 144 decisions in the control group violates the waiting time rule; in period 2, an average of 51% of the 144 decisions violates the waiting time rule, and so on. The vertical lines in the graphical part of Fig. 1 mark the introduction of nudge A (information with pictures) or B (information with pictures and an additional social comparison) from period 4 onwards.

The graph in Fig. 1 shows that although the share of non-compliance behavior fluctuates from period to period for the control groups in both samples, agricultural students and fruit growers, there is no discernible patterns of behavioral changes over periods. With respect to the treatment groups, a clear reduction in the share of non-compliance can be identified after the introduction of nudges. In the group of agricultural students, the average share of non-compliance behavior decreases by 17.95 percentage points from period 3 to period 4 in nudge treatment A and by 23.61 percentage points in nudge treatment B. A similar trend can be seen among treated fruit growers: From period 3 to period 4, the average share of non-compliance decreases by 5.56 percentage points in nudge treatment A and by 4.17 percentage points in nudge treatment B.
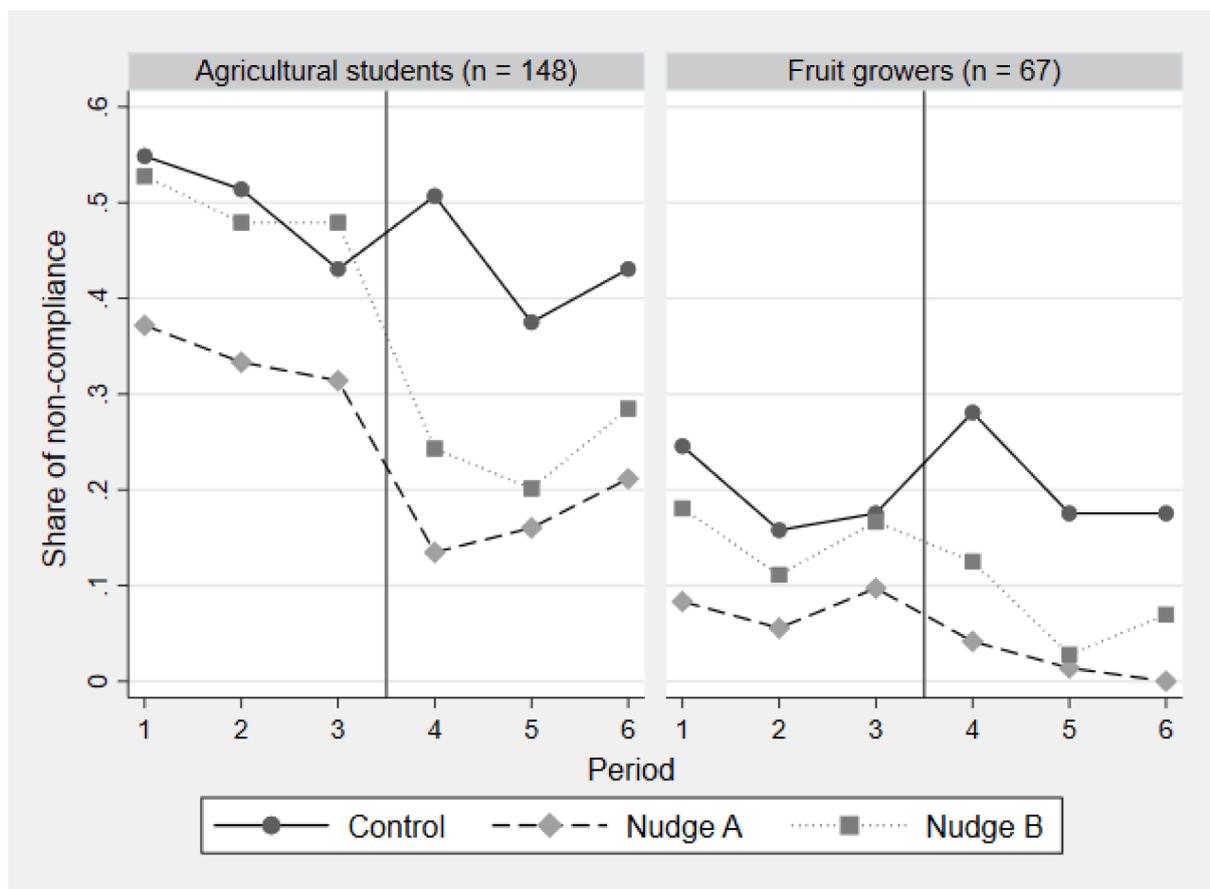
The average share of non-compliance in % for each period is detailed in the table below the graph in Fig. 1. Prior to the introduction of nudges (periods 1-3), the difference in the average share of non-compliance between the control and treatment groups for agricultural students is

statistically significant (period 1, $p = 0.003$; period 2, $p = 0.004$; period 3, $p = 0.011$, Chi-squared test) on a 5%-significance level. For fruit growers, this difference is only statistically significant in period 1 (period 1, $p = 0.042$, Chi-squared test) on a 5%-significance level. These non-treatment-related behavioral differences between the control and treatment groups may be due to the vagaries of randomization and the relatively small group sizes. After the introduction of nudges (periods 4–6), as expected, the difference between the control and treatment groups is statistically significant for both samples of agricultural students and fruit growers.

Table 2 summarizes the average categorial and metrical non-compliance behavior before and after the introduction of nudges A and B. The upper part of Table 2 shows agricultural student's behavior and the lower part shows fruit grower's behavior. For both groups, the table is subdivided into an average share of non-compliance, average non-compliance extent in days and average severity of non-compliance in the deviant population in rule-breaking days before and after the treatment. The share of non-compliance shows how many decisions in percentage are made in violation of 14-day pre-harvest interval rule on average. The average non-compliance extent in days presents the average difference between the 14-day pre-harvest interval and waiting days (date for harvest minus date for pesticide application) chosen by the respondents. This variable takes the values of zero if the waiting days equal to or more than 14 days. The average severity of non-compliance in the deviant population in case of rule-breaking only considers decisions that violate the 14-day pre-harvest interval rule. Note it is possible that none or perhaps all decisions of a participant are considered, depending on whether each decision itself violates the 14-day pre-harvest interval. This measure is particularly relevant in providing policy implications as to whether green nudges would have a greater impact on those higher at risk of violating the pre-harvest interval.

As illustrated in Fig. 1, Table 2 also demonstrates the considerable differences in pre-treatment non-compliance behavior between the control and treatment groups in terms of both categorial and metrical values, as summarized below:

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[6] Although one subject made six decisions in one period (date of pesticide application and date of harvest for each of three apple varieties), for the purposes of this study, we are more interested in whether the person violates the 14-day pre-harvest interval and how many days that interval is violated, rather than the exact dates of pesticide application and harvest. Therefore, we calculated a waiting day, i.e. the date of harvest minus the date of pesticide application, and used this for the following analysis. In other words, only three decisions by one participant in one period are considered in the following analysis.

		Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Agricultural students	Control (n = 48) [b]	54.86%	51.39%	43.06%	50.69%	37.50%	43.06%
	Nudge A (n = 52) [b]	37.18%	33.33%	31.41%	13.46%	16.03%	21.15%
	Nudge B (n = 48) [b]	52.78%	47.92%	47.92%	24.31%	20.14%	28.47%
	p-value [a]	0.003	0.004	0.011	<0.001	<0.001	<0.001
Fruit growers	Control (n = 19) [b]	24.56%	15.79%	17.54%	28.07%	17.54%	17.54%
	Nudge A (n = 24) [b]	8.33%	5.56%	9.72%	4.17%	1.39%	0.00%
	Nudge B (n = 24) [b]	18.06%	11.11%	16.67%	12.50%	2.78%	6.94%
	p-value [a]	0.042	0.164	0.362	<0.001	<0.001	0.001

[a] Chi-squared test
[b] n = Number of subjects

Fig. 1. Average share of non-compliance in % in each period for the students ($n = 148$) and fruit growers ($n = 67$).

a) The share of non-compliant decisions of experimental subjects (fruit growers: 19.30% in the control group vs. 7.87% and 15.28% in group A and B; agricultural students: 49.77% in the control group vs. 33.97% and 49.54% in group A and B);
b) The overall extent of non-compliance in terms of illicitly exceeding of the pre-harvest interval (fruit growers: 0.38 days in the control group vs. 0.17 and 0.24 days in group A and B; agricultural students: 1.42 days in the control group vs. 0.77 and 1.38 days in group A and B);
c) The average severity of non-compliance in the deviant population (fruit growers: 1.97 days in the control group vs. 2.12 and 1.58 days in group A and B; agricultural students: 2.85 days in the control group vs. 2.27 and 2.79 days in group A and B).

To address the concern of unbalanced pre-treatment outcomes between the control and treatment groups, this study focuses on a within-subject perspective for testing Hypotheses 1, which was also implemented by Peth and Mußhoff (2020). To test Hypotheses 2 and 3, we compare the behavioral changes induced by nudges A and B as well as the response of agricultural students and fruit growers.

As the business management game has six periods, the question now is whether there will be observable learning effects. Directly testing for learning effects is difficult, but examining the changes in behavioral patterns across periods in the control groups may provide some suggestive evidence. In periods 4–6, the average share of non-compliance in the control group of fruit growers is 1.75 percentage points higher than in periods 1–3. However, a Chi-squared test ($p = 0.686$) provides evidence that no statistically significant change in behavior can be observed over periods. For the agricultural students, the share of non-compliance in the control group in periods 4–6 is 6.02 percentage points lower than before. A Chi-squared test ($p = 0.076$) provides an empirical indication of a statistically significant learning effect on a 10%-significance level. Regarding the overall extent of non-compliance, the violations of the pre-harvest interval in periods 4–6 for the control fruit growers are 0.11 days longer and for the control agricultural

Table 2
Average of non-compliance before and after the use of nudges.

Agricultural students (n = 148) [d]	Period 1 to 3	Period 4 to 6	Difference after and before the treatment
Average share of non-compliance (in %)			
Control group (n = 48)	49.77%	43.75%	−6.02 (p = 0.076) [a]
Group A (n = 52)	33.97%	16.88%	−17.09 (p < 0.001) [a]
Group B (n = 48)	49.54%	24.31%	−25.23 (p < 0.001) [a]
Group A vs. Group B			p = 0.355 [a]
Average non-compliance extent (in rule-breaking days)			
Control group (n = 48)	1.42	1.28	−0.14 (p = 0.066) [b]
Group A (n = 52)	0.77	0.34	−0.43 (p < 0.001) [b]
Group B (n = 48)	1.38	0.67	−0.72 (p < 0.001) [b]
Group A vs. Group B			p = 0.144 [b]
Average severity of non-compliance in the deviant population (in rule-breaking days)			
Control group (n = 38)	2.85	2.92	0.06 [c]
Group A (n = 36)	2.27	2.04	−0.23 [c]
Group B (n = 36)	2.79	2.75	−0.04 [c]
Fruit growers (n = 67) [d]			
Average share of non-compliance (in %)			
Control group (n = 19)	19.30%	21.05%	1.75 (p = 0.686) [a]
Group A (n = 24)	7.87%	1.85%	−6.02 (p = 0.004) [a]
Group B (n = 24)	15.28%	7.41%	−7.87 (p = 0.010) [a]
Group A vs. Group B			p = 0.848 [a]
Average non-compliance extent (in rule-breaking days)			
Control group (n = 19)	0.38	0.49	0.11 (p = 0.702) [b]
Group A (n = 24)	0.17	0.05	−0.12 (p = 0.004) [b]
Group B (n = 24)	0.24	0.13	−0.11 (p = 0.011) [b]
Group A vs. Group B			p = 0.621 [b]
Averge severity of non-compliance in the deviant population (in rule-breaking days)			
Control group (n = 14)	1.97	2.31	0.34 [c]
Group A (n = 11)	2.12	2.50	0.38 [c]
Group B (n = 12)	1.58	1.69	0.11 [c]

[a] Chi-squared test.
[b] Mann-Whitney U test.
[c] A mean comparison is not feasible as not all decision can be considered.
[d] n = Number of subjects.

students 0.14 days shorter, compared to the first three periods. The Wilcoxon Signed-Rank tests (p = 0.702 and p = 0.066, respectively) show that the differences are statistically significant on a 10%-significance level for the agricultural student sample, but statistically insignificant for the fruit grower sample. This provides some suggestive evidence on the learning effect for the agricultural student sample. Nevertheless, the study proceeds with the detailed within-subject mean comparison and the implications of a learning effect for the agricultural student sample is discussed in Section 5.

Thus, to assess the effects of nudges A and B, we compare the average non-compliance behavior before and after the introduction of nudges in the samples of fruit growers and agricultural students. The lower part of Table 2 shows that the average share of non-compliance of the fruit growers decreases from 7.87% to 1.85% in group A and from 15.28% to 7.41% in group B. These before- and after-treatment differences are statistically significant on a 1%-significance level (Chi-squared test; p = 0.004 for group A and p = 0.010 for group B). A similar pattern can be observed for agricultural students in the upper part of Table 2: The average share of non-compliance decreases from 33.97% to 16.88% in group A and from 49.54% to 24.31% in group B. The differences within the groups of agricultural students are statistically significant on a 1%-significance level (Chi-squared test; p < 0.001 for group A and p < 0.001 for group B).

When comparing the fruit growers treatment groups A and B in the lower part of Table 2, average non-compliance extent in days also decreases: It decreases from 0.17 to 0.05 days in group A and from 0.24 to 0.13 days in group B. The sample of agricultural students exhibits a similar pattern, as reported in the upper part of Table 2: The average

non-compliance extent decreases from 0.77 to 0.34 days in group A and from 1.38 to 0.67 days in group B. Results from the Wilcoxon Signed-Rank tests show that the before- and after-treatment differences within the groups of fruit growers (Group A, p = 0.004; Group B, p = 0.011) and students (Group A, p < 0.001; Group B, p < 0.001) are statistically significant on a 5%-significance level. A suspicious difference between fruit growers and agricultural students is observed for the average severity of non-compliance in the deviant population. While for deviant fruit growers, the number of rule-breaking days increase after the introduction of nudges in group A (0.38 days) and group B (0.11 days), the expected opposite is observed for the deviant agricultural students in group A (−0.23 days) and group B (−0.04 days). An increase in the number of rule-breaking days by fruit growers may suggest reactance or defense reaction in response to the nudge treatments.

With regard to the magnitudes of the nudges, results for the agricultural students suggest that nudge B is stronger as it decreases the average share of non-compliance by 25.23% in comparison to nudge A with a decrease in the average share of non-compliance by 17.09%. Similarly, average non-compliance extent in rule-breaking days is decreased by 0.71 days in group B in comparison to 0.43 days in group A. However, this cannot be observed to the same extent for the fruit grower sample. Nudge B decreases the average share of non-compliance by 7.87% and nudge A by 6.02%. The average non-compliance extent in rule-breaking days is decreased by 0.12 days in group A and by 0.11 days in Group B. Nevertheless, the decrease in average share of non-compliance and the non-compliance extent in days is not statistically significantly higher for nudge B in the agricultural students' sample (Chi-squared test: p = 0.355; Mann-Whitney U test: p = 0.144) and in the fruit growers' sample (Chi-squared test: p = 0.848; Mann-Whitney U test: p = 0.621).

The concrete findings of Table 2 can be summarized as follows: First, both green nudges had a preventive effect in the experiment and the average non-compliance extent was considerably reduced. Second and more specifically, both green nudges worked for the agricultural students as well as the fruit growers in the same direction. Third, the nudges are much less effective for the deviant subpopulation in the fruit grower sample and defiant behavior to the nudges can be suspected. Fourth, a nudge with a social dimension is not statistically significant more effective than a nudge without a social dimension. Fifth, average share and extent of the non-compliance differ widely between the samples of fruit growers and agricultural students in periods 1–3 and 4–6. Fruit growers have a lower frequency and extent of non-compliance with the pre-harvest interval regulations compared to agricultural students, in line with other studies showing that student samples have a higher tendency to behave more non-compliantly than a non-student sample (e. g. Choo et al., 2016).

4.3. Robustness check

To verify the result robustness of the mean comparison of the non-compliance behavior, further regression analyzes are performed on participant's decisions in the business management game using a generalized additive model for location, scale and shape environment (GAMLSS) and a propensity score matched difference-in-difference (DID) model.

GAMLSS is a general class of (semiparametric) regression models proposed by Rigby and Stasinopoulos (2005). These models feature a large variety of response distributions for the dependent variable. Moreover, individual random intercepts can be incorporated as additive terms. For a detailed description of this model class and its full capabilities, reference is made to Rigby and Stasinopoulos (2005) and Stasinopoulos and Rigby (2008). Table 3 shows the results of the Logit and Poisson Inverse Gaussian (PIG) distributions for the pooled sample. Our analysis revealed that a Logit distribution and a PIG distribution are appropriate choices for the distribution of the dependent variables (probability of non-compliance and the average non-compliance extent

Table 3
Results of the GAMLSS model for the pooled sample ($n = 215$).

	Estimate	Exp (estimate)	Standard error	t-statistic	*p*-value
probability of non-compliance (Logit distribution)					
Intercept	0.85	2.34	0.14	6.26	< 0.001
Dummy control group	−0.26	0.77	0.25	−1.00	0.315
Dummy group A	−2.16	0.11	0.26	−8.18	< 0.001
Dummy group B	−2.10	0.12	0.25	−8.14	< 0.001
Dummy fruit grower	−2.02	0.13	0.19	−10.50	< 0.001
average non-compliance extent (PIG distribution)					
Intercept	−3.81	0.02	0.06	−57.61	< 0.001
Dummy control group	−0.19	0.81	0.12	−1.50	0.132
Dummy group A	−0.74	0.47	0.14	−5.27	< 0.001
Dummy group B	−0.61	0.54	0.12	−5.07	< 0.001
Dummy fruit grower	−0.76	0.47	0.11	−6.79	< 0.001

in days, respectively). Based on the within-subject comparisons, both regression models use decisions made in periods 1-3 (before treatment) as a reference. The control group dummy is included to test whether there is a statistically significant change in the behavior of the control subjects in periods 4-6, and the inclusion of the fruit grower dummy aims to identify the heterogeneity of effects between agricultural students and fruit growers.

The upper part of the Table 3 shows that compared to periods 1-3, nudge A decreases the probability of non-compliance by 88.47% ($(e^{-2.16} - 1) x100$) and nudge B decreases it by 87.75% ($(e^{-2.10} - 1) x100$) on a 1%-significance level. While the changes in the probability of non-compliance for both treatments A and B are statistically significant ($p < 0.001$), the change is not statistically significant for the control group ($p = 0.315$). Similar results in terms of the non-compliance extent are shown in the lower part of Table 3: Compared to the reference periods 1-3, nudge A decreases the non-compliance extent by 52.28% ($(e^{-0.74} - 1) x100$) and nudge B decreases it by 45.66% ($(e^{-0.61} - 1) x100$) on a 1%-significance level. While the effects are statistically significant for both treatment groups ($p < 0.001$), it is not the case for the control group ($p = 0.132$). Hence, the GAMLSS provides further evidence that both nudges decrease non-compliant behavior by agricultural students and fruit growers. However, nudge B is not stronger than nudge A as previously suggested since the decrease in non-compliant behavior seems to be stronger for nudge A in both models. Lastly, the results of the fruit grower dummy reveal that the probability of non-compliance and the non-compliance extent are statistically significantly smaller for fruit growers than for agricultural students (86.73 % ($(e^{-2.02} - 1) \times 100$), $p < 0.001$; 53.23 % ($(e^{-0.76} - 1) \times 100$), $p < 0.001$, respectively).

Given the experimental design and data structure, an alternative empirical approach is the DID, which allows us to assess the effect of nudges by comparing non-compliance behavior in the control and treatment groups before and after the treatment periods. Unlike the GAMLSS model, which estimates the effects of both nudge A and nudge B simultaneously in one equation, the effects of two nudge treatments can only be assessed by separate regression specifications under the framework of the DID.

The critical assumption of the DID approach is the "common trends" assumption, which states that in the absence of a treatment, the outcome of the control and treatment groups would follow the same trend over time (Ryan et al., 2019). Although this assumption is not directly

testable, comparing the evolution of pre-treatment non-compliance behavior can provide some suggestive evidence. As shown in Fig. 1, there are statistically significant differences in the average share of non-compliance between the control group, group A and group B in periods 1–3 in both agricultural student and fruit grower samples, suggesting that the "common trends" assumption is violated. To address this issue, we follow Ryan et al. (2019) and perform the DID estimation with a propensity score weighting, as also implemented by Smith and Todd (2005). Propensity score matching is performed by a one-to-one matching with replacement, calipers of 0.9 and implementation of common support. Decisions on non-compliance for each period prior to the start of nudges (periods 1-3) are used for matching. Treatment groups A and B are matched separately with the control group, resulting in two independent matching procedures. The weights generated from the matching procedures are used as controls in the DID specifications. In addition, we control for the socio-demographic characteristics (Table 1). The results are shown in Table 4 with the pooled sample for three dependent variables:

(a) Dummy for non-compliant behavior;
(b) Non-compliance frequency;
(c) Non-compliance extent in days.

First and foremost, Table 4 confirms the results of Table 2 and Table 3 that both nudging treatments reduce the non-compliant behavior since the coefficients have the expected negative sign and are statistically significant on a 5%-significance level. However, results from the propensity score matched DID estimation do not give a clear picture whether nudge A or B is more effective. In the model (a) using a logit model with the non-compliance dummy as the dependent variable, the coefficient on nudge A is larger, while the coefficients on nudge A in the other two models (b) and (c) are smaller than coefficients on nudge B. Moreover, the interaction term *Treatment * Fruit growers* in the model (a) is not statistically significant. This result indicates that fruit grower's behavior is not statistically significantly differently influenced by the treatment than the behavior of agricultural students on a 10%-significance level. However, results from the other models show a different picture in which the interaction terms are statistically significant on a 10%-significance level. Accordingly, the results allow the conclusion that the fruit growers respond differently to the nudges or are differently receptive to the nudges' effect than agricultural students. Hence, a sample of professionals should be used if the nudges' specific magnitude is of interest rather than just the directional effect of the nudges.

In conclusion, the results of robustness checks (GAMLSS and propensity score matched DID estimation) confirm that nudges can reduce non-compliant behavior, while adding a social dimension does not necessarily unequivocally increase the effectiveness. Furthermore, the responsiveness to the nudges in terms of directing the behavior in the desired way of agricultural students and fruit growers is comparable. However, results indicate that the effectiveness of nudges differs between agricultural students and fruit growers.

5. Discussion

In summary, this study confirms results of the literature transferred in the field of fruit growers and compliance with pre-harvest intervals after the pesticide application. The introduction of nudging helps to influence the test persons to make the decisions desired by the nudge architect. In specific, both green nudges (with and without a social dimension) are effective in reducing the non-compliant behavior of participants. Hence, H1 can be given support. However, it could not be confirmed that the social dimension adds to the effectiveness of the green nudge. Therefore, H2 cannot be supported. Lastly, the responsiveness to the nudges in terms of directing the behavior in the desired way of agricultural students is comparable to that of the fruit growers in this context. Thus, H3 is supported by our results. Details are discussed

Table 4

Propensity score matched difference-in-difference (pooled sample analysis) ($n = 215$).

	(a) Dependent variable: Non-compliance dummy				(b) Dependent variable: Non-compliance frequency				(c) Dependent variable: Non-compliance extent in days			
	Nudge A		Nudge B		Nudge A		Nudge B		Nudge A		Nudge B	
	(1)	p-value	(2)	p-value	(3)	p-value	(4)	p-value	(5)	p-value	(6)	p-value
Treatment [a]	−0.91 (0.28)	0.001	−0.82 (0.32)	0.011	−0.38 (0.14)	0.007	−0.56 (0.17)	0.001	−0.31 (0.13)	0.020	−0.56 (0.19)	0.004
Age	0.02 (0.03)	0.654	0.00 (0.03)	0.918	0.01 (0.01)	0.449	0.01 (0.01)	0.398	0.01 (0.01)	0.317	0.02 (0.02)	0.243
Agricultural association	−0.28 (0.53)	0.595	−0.22 (0.52)	0.665	−0.10 (0.24)	0.675	−0.07 (0.26)	0.798	−0.14 (0.21)	0.488	−0.20 (0.24)	0.412
Agricultural training	0.03 (0.60)	0.964	−0.21 (0.48)	0.661	−0.02 (0.28)	0.946	−0.15 (0.26)	0.582	−0.13 (0.24)	0.597	−0.17 (0.34)	0.619
Household size	0.04 (0.09)	0.675	−0.07 (0.11)	0.521	−0.01 (0.04)	0.737	−0.06 (0.06)	0.276	−0.02 (0.03)	0.468	−0.09 (0.08)	0.264
Gender	0.19 (0.56)	0.736	0.26 (0.49)	0.596	0.09 (0.25)	0.718	0.04 (0.23)	0.876	0.16 (0.22)	0.477	−0.02 (0.23)	0.916
University degree	−1.16 (0.75)	0.123	−0.95 (0.66)	0.147	−0.42 (0.29)	0.146	−0.35 (0.30)	0.238	−0.26 (0.22)	0.236	0.10 (0.48)	0.827
Risk attitude (HLL) [b]	−0.30 (0.16)	0.053	−0.45 (0.17)	0.008	−0.14 (0.06)	0.025	−0.23 (0.08)	0.004	−0.13 (0.06)	0.040	−0.20 (0.11)	0.086
Law abidance [c]	0.07 (0.10)	0.474	−0.02 (0.11)	0.850	−0.00 (0.04)	0.953	−0.02 (0.06)	0.684	−0.01 (0.04)	0.731	−0.05 (0.07)	0.465
*Treatment * Fruit growers* [a]	−0.81 (0.79)	0.303	0.22 (0.69)	0.748	0.33 (0.19)	0.078	0.46 (0.25)	0.068	0.33 (0.16)	0.042	0.52 (0.24)	0.031
Constant	0.51 (1.60)	0.749	3.56 (1.54)	0.021	1.57 (0.75)	0.037	2.92 (0.73)	0.000	1.44 (0.75)	0.059	2.67 (0.94)	0.005
R-squared Observations	0.12 1518		0.16 1434		0.14 1518		0.23 1434		0.12 1518		0.16 1434	

[a] *Treatment* is obtained from the interaction of a treated dummy variable and a post-treatment dummy variable. The treated dummy takes the value of 1 for subjects assigned to the treatment groups (nudge A or B), and 0 otherwise. The post-treatment dummy takes the value of 1 for periods 4-6 after the introduction of nudges, and 0 otherwise. Coefficient in column (1) for agricultural students: -0.91; coefficient in column (1) for fruit growers: $-1.72 = (-0.91) + (-0.81)$.

[b] Holt-and-Laury values; 0–3 = risk-seeking, 4 = risk neutral, 5–10 = risk averse.

[c] Law abidance self-assessment scale; 0–4 = rather not law-abiding, 5 = neither nor law-abiding, 6–10 = rather law-abiding

Standard errors are in parentheses and clustered at the individual level

and presented in the following.

Looking at both samples, the nudge with the additional social comparison (nudge B) seems to have a stronger effect on the average share of non-compliance than the nudge with just information and pictures (nudge A). In specific, the within-subject perspective shows a larger decrease in the average share of non-compliance in group B than in group A after the introduction of nudges. However, a stronger effect of nudge B in the average non-compliance extent in days is only observed for the sample of agricultural students but not for fruit growers. Nevertheless, the differences in the decrease of the non-compliance behavior are not statistically significant. Performing regression analysis, results from the GAMLSS estimation suggest that a nudge without a social dimension is more effective. A stronger effect for nudge B was expected due to the fact that necessary information for decisions are usually obtained socially (Asch, 1995; Thaler & Sunstein, 2008). Decisions of others can serve as a guide and thus an anchor heuristic. Anchor heuristics are one of the tools that help individuals make decisions faster and with less effort (Tversky & Kahneman, 1974). Therefore, the present study does not leave any statement preference for a certain nudge (with or without a social dimension) in practice. Given the heterogeneity of regulations and their acceptance by those regulated, it would be even more overhasty regarding the practical use to generalize and conclude that one should prefer a social comparison nudge or a nudge without a social dimension in general. Some other studies already give the indication that social comparisons might work for one group but not for others (e.g. Sunstein et al., 2007; Murray & Matland, 2015). In the agricultural economics context, the results are in line with Chabé-Ferret et al. (2019), Peth et al. (2018) as well as Massfeller et al. (2022), but in contrast to Kuhfuss et al. (2016a, b). One possible reason for the inconsistent results is that the experimental setting may cause the social nudge to be less effective, as discussed by Chabé-Ferret et al. (2019). In our study, the social comparison was only used in combination with the purely informational nudge. For future research, it could

be of interest to compare the social comparison nudge, the informational nudge and a combination of both (e.g. Howley & Ocean, 2021). This would allow for a better assessment of the effects of a nudge with a social comparison alone and shed more light on this counterintuitive result in this context.

Looking in detail at the fruit growers, the results are conspicuous. Firstly, the average share of non-compliance and the average non-compliance extent in days are on a lower level in comparison to the agricultural students in each group, even in the control group. These findings suggest that the professionals are more compliant than the students. Secondly, the average severity of non-compliance extent in case of rule-breaking in the deviant fruit growers increased from periods 1-3 to periods 4-6. One potential reason for this behavior could be the professional experience of the fruit growers. It can be assumed that all fruit growers know exactly when to apply the pesticide after their many years of work. As a result of the funds of knowledge and expertise, fruit growers are at a lower level of non-compliance and are more likely to react defensively to the nudges if they perceive it clearly interfering and patronizing. The defensive behavior in case of the average severity of non-compliance extent in rule-breaking days in the deviant population could be reflected by reactance. Reactance is a defensive reaction against restrictions from outside, which are considered illegitimate (Peth et al, 2018). This effect can occur when a political measure is not accepted by the public and a negative attitude arises (Jensen, 2017). This is the case when the participant has the feeling of being patronized (Le Grand & New, 2015). These findings underline the importance of the correct use of nudges in practice. If the objectives of a policy failed, the measures could backfire to a large extent. Knowledge about the correct use of nudges in practice can only be gained through practice-orientated experiments such as the business management game presented in this study. Reactance should be in the focus of future studies.

In addition, this study also confirms the effectiveness of nudges in this context and differences can be seen in detail. On the one hand, both

samples reduced the non-compliance behavior. On the other hand, it was surprisingly found that both informational and social nudges cause reactance for some deviant participants in the sample of fruit growers. Peth et al. (2018) came to comparable findings regarding the effectiveness of nudges with respect to compliance of water protection rules in a business management game. However, the authors could only measure reactance among deviant farmers for the nudge with the social dimension. This study reveals new findings for the practical use. This demonstrates the variability in the dimensions of human behavior and the importance of reviewing appropriate tools in different contexts before scaling up. Furthermore, this underlines the previous implication that reactance should be in one focus of future studies. In addition to these findings, the direction of the effects of nudges on non-compliance is consistent across the samples of both fruit growers and agricultural students. Two implications can be derived from this: First, green nudges can be an effective instrument to foster more sustainable farming practices. Although Benartzi et al. (2017) conclude that nudging is more preferable in terms of cost than implementing other policies, green nudges in our context should be considered a complement to the authorities' controls, rather than a substitute for them (e.g. Ferrari et al., 2019). Second, the comparability in terms of responsiveness to the nudges of the fruit growers and agricultural students was confirmed for directing the behavior in the desired way. The results underline the implications by Ferré et al. (2017) that if students are used in policy-relevant experiments, they should be as close to the subject matter as possible. Differences in the behavior of students and professionals, as also observed in this experiment, can be attributed to several reasons (e.g. cognitive skills, experience) as summarized by Frigau et al. (2019). Hence, an agricultural student sample is appropriate to determine whether green nudges are working or not, but the magnitude of a nudge should be examined using a professional sample (Peth & Mußhoff, 2020) as our result also show fruit growers are differently receptive to the nudges than agricultural students.

With regard to the experimental methodology applied, an extension of the business management game through the following aspects would be conceivable. First, the inclusion of social norms in nudging addresses, among other things, the influence of social shaming (van Aaken, 2015). It would be interesting to investigate the effectiveness of social shaming on compliance behavior by incorporating a non-compliance detector into the business management game, which would communicate detected non-compliant behavior of participants to the rest of the group. Second, it would be interesting to additionally evaluate how the participants assess applied nudge scenarios. This would allow for obtaining more precise insights into whether the nudges are perceived as patronizing, helpful or even disruptive. Dogruel (2019) examined the intrusiveness of a nudge which targeted heuristic decision-making or deliberate decision-making in the context of media. In this study, she was able to gain a more precise insight into the acceptance of nudge designs. Although these are not specific nudges, this study illustrates how this approach can provide additional helpful information and a deeper understanding of a particular behavior. A third extension, which has already been touched upon above, would be to leave the online game environment. This study shows that the proposed nudges work in the business management game environment. However, an important consideration when conducting business management games is experimental realism, for example, the closeness to reality and the level of game complexity (Dieguez-Barreiro et al., 2011). Nevertheless, studies have shown that financial incentives in economic experiments as provided in this study can help to maintain participants' concentration and lead to less variance in results (Smith & Walker, 1993; Camerer & Hogarth, 1999). There is no doubt that nudges can generally lose their effect if an attempt is made to adapt the behavioral economic instrument to another context, which could have many different reasons, such as creation of confusion (Sunstein, 2017). It is therefore essential to conduct a deeper investigation into whether the nudges used in this study can have a similar effect in reality. Accordingly, the next step

would be to examine the nudging effects observed in the business management game on actual agricultural practices in the field. A comparison of fruit growers in the field and online farming environment with agricultural students in an online farming environment could provide a valuable deeper understanding of the nudges' effectiveness which is fruitful for ex-ante policy impact assessment. This extension could also provide further evidence as to whether agricultural students can be used as a comparable alternative for professional fruit growers to analyze the direction of action of the nudges.

Nonetheless, this study has some limitation. A larger sample size is needed to further check the robustness and generalizability of the findings. This could also ensure a more balanced distribution among the experimental groups. In the present study, evidence on learning effects could be presented for the agricultural student sample, but not for the fruit grower sample. This is plausible as students might be more familiar with the experimental environment and therefore more likely to develop strategies to achieve higher payoffs than the fruit growers. In addition, students might be less familiar with managing an apple orchard than the fruit growers and therefore are learning how to manage an apple orchard according to the rules during the game. Future studies with agricultural student samples need to take into account that potential learning effects may be more likely to occur with them than with farmers. In this regard, to gain further insights into the comparability of agricultural students and fruit growers, and to get a better understanding of the generalizability of our results and implications, this study should be replicated in other countries with the modifications addressed before.

6. Conclusion

Pre-harvest interval rules aim to reduce residues of pesticides, which are often present in fruits, for example, and thus represent a potential threat for consumers. Comprehensive controls of compliance with the interval rules by appropriate institutions are complex and cost-intensive. Therefore, instruments which do not require full controls, such as nudges, can be a worthwhile additional instrument to consider. This experimental study with 67 German fruit growers and 148 German agricultural students investigated the preventive effects of green nudges on compliance with the pre-harvest interval rule in apple production. In specific, two nudges were designed and examined. Nudge A was based on information with pictures highlighting the negative environmental impacts of a rule violation and nudge B additionally pointed out that other fruit growers in the area comply with the pre-harvest interval rule. Both green nudges were effective preventive measures in the business management game and reduced the probability of violating the pre-harvest interval and the average non-compliance extent in days, suggesting that its use in practice as a complement to controls by authorities could be promising. However, the present study does not leave any statement preference for a certain nudge scenario (with or without a social dimension) in practice. Furthermore, this study addressed if agricultural students could be used as a convenience group for fruit growers. This can be confirmed as the study showed that the agricultural student sample can be used to examine how the response to the nudges can be steered in the direction. Still, a more in-depth analysis with a sample of professionals should be used if the nudges' magnitude is of interest. Lastly, this study provides several points to be further explored in the future.

Declarations of Competing Interest

None.

Data availability

Data will be made available on request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.socec.2022.101963.

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Further reading

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