Nudging farmers to comply with water protection rules – Experimental evidence from Germany

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Abstract:

Nitrogen runoffs induced by agricultural fertilisation cause serious environmental damage to surface waters. Environmental and consumer protectionists demand government intervention to mitigate these externalities. With this in mind, the present study examines the effects of nudge-based regulatory strategies. We use an incentivised single-player multi-period business management game as an experimental device to study how nudges affect compliance with the minimum-distance-to-water rule in a sample of German farmers. We investigate two different nudge treatments: a nudge with information and pictures showing environmental and health damages that are presumably caused by breaching the minimum-distance-to-water rule, and a nudge with an additional social comparison suggesting that the majority of farmers in the same region comply with the rule. We observe three core experimental outcomes: first, nudging has a preventive effect and reduces the share of non-compliant participants. Second, against all expectations, the preventive effect of the nudge with an additional social comparison is weaker than that of the nudge with information and pictures alone. Third, despite the overall positive effects of nudging, the nudge with social comparison even increased the severity of non-complying behaviour in the deviant subpopulation.

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JEL Codes: Q58, Q28

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Abstract

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Key Words

Green nudge, behavioural economics, business management games, ex-ante policy impact analysis

JEL Classifications

Q18, Q28, Q53, Q58, D91

1. Introduction

With a share of 63 % in Germany, agricultural production activities are the major source of nitrogen emissions, which can be traced back to the use of nitrogen based fertiliser or livestock manure (Geupel and Frommer, 2016). High nitrogen loads can have detrimental effects on aquatic ecosystems and entails risks for human well-being (Pretty et al., 2001). Negative externalities of agricultural production activities, such as the leaching and surface run-off of applied nitrogen fertiliser, constitute a severe threat to surface water quality. High nutrient inputs support eutrophication, which leads to accelerated spread of algae, and consequently to oxygen depletion and a decrease of biodiversity in surface waters (Rabalais, 2002). Brink et al. (2011) estimate the economic costs of these externalities related to water pollution through nitrate fertiliser use at 5 to 24 Euros per kilo of fertiliser. To reduce these externalities, regulatory measures are required with the intent of changing farmers' behaviours, and subsequently reduce the presence of fertilisers in surface waters.

The objective of the EU's Water Framework Directive (Directive 2000/60/EC), also including the Nitrate Directive (Council Directive 91/676/EEC), is to protect and improve water quality. By 2027, all European surface waters should be of a good ecological and chemical status (BMUB and UBA, 2016). In order to meet the requirements of the Water Framework Directive, a range of environmental regulations exist. In Germany, the Water Framework Directive and the Nitrate Directive are implemented by the recently amended German Fertiliser Application Ordinance (DüV, 2012) and the Fertiliser Act (DüngG, 2017). One important measure to prevent nitrogen run-off is the rule of minimum distance. According to the DüV, a distance of four meters (before 02 June 2017 three meters) to the upper edge of the embankment of a body of water must be maintained when applying fertiliser. Currently, the nitrogen concentration in surface waters is still too high. In 2015, the target value of the LAWA (German Working Group on water issues of the Federal States and the Federal Government represented by the Federal Environment Ministry) of 2.5 mg/l nitrate – that corresponds, in accordance to the quality classification of bodies of water, to quality category II or better – was exceeded at 81 % of the measuring points (BMUB and BMEL, 2017; UBA, 2017).

Controls and sanction reinforcement represent traditional measures of regulatory enforcement of regulations such as the minimum-distance-to-water rule. Controls and sanctions are associated with high costs. Furthermore, there is a fundamental difficulty in identifying the place and time of discharge. The traceability to the polluter is naturally hindered by a rapid removal of nutrients in waters. Regulation, control and the threat of financial sanctions do not always suffice to induce the desired behaviour (Dowd et al., 2008). In order to steer the behaviour of actors, more and more behavioural insights have been taken into account in common regulatory practice recently (Sousa Lourenço et al., 2016). Especially in the US and the UK, behavioural insight units have been established to design efficient policy measures (Halpern, 2015; OECD, 2014). The application of "nudging" is a new promising approach in policy making. Since the term was introduced by Thaler and Sunstein (2008), it has evolved to a popular policy instrument because of its cheap implementation costs and effectiveness. A nudge "alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler and Sunstein, 2008, p. 6). Although nudging is heavily discussed in terms of manipulation, paternalism and other ethical concerns (Gigerenzer, 2015; Hansen and Jespersen, 2013; Hausman and Welch, 2010), it might be a cost-efficient new "soft" policy tool (Michalek et al., 2016). Nudges are particularly popular in the research field of health economics when it comes to teaching people healthy eating habits (Arno and Thomas, 2016). But also in the area of environmental policy, so-called "green nudges" are increasingly being researched (Croson and Treich, 2014; Schubert, 2017).

So far, a nudge is regarded primarily as opportunity to induce a desired behaviour, without falling back on regulatory measures and their costly enforcement (Thaler and Sunstein, 2008). Furthermore, a nudge can be applied as a preventative measure to promote compliance with existing regulation, and if applicable, a substitute for intense and costly control and sanction measures. Studies on the effect of nudging in agriculture, and especially on the prevention of non-compliance, are as of yet scarce. In a framed laboratory experiment, Czap et al. (2015) investigate how empathy nudges can be used to promote environmental friendly behaviour in farmers. Their results show that the appeal to put oneself in the shoes of a person who is affected by environmentally damaging behaviour can strengthen environmental protection. Kuhfuss et al. (2015; 2016) show that by the usage of social norms in nudging, farmers can be persuaded to participate in an agri-environmental scheme, or continued participation in a scheme that has already begun.

A policy impact analysis can be carried out both ex post and ex ante (Henning and Michalek, 2008). In an ex-post analysis, the regulatory measure is evaluated retrospectively in a real decision-making environment. One disadvantage of this approach is a low internal validity, since controlling the environment and comparing under a ceteris-paribus assumption are hardly possible (Patel and Fiet, 2010). This problem can be circumvented with controlled field studies. However, there are limitations due to high implementation costs as well as legal and ethical concerns (Burtless, 1995). The aim of an ex-ante analysis is to assess the impact of a policy measure prior to its implementation. Thus, costs can be kept low. A starting point for ex-ante evaluations can be an experimental setting in the form of a business management game, with which the context-dependant decision-making behaviour of humans can be observed (Mußhoff and Hirschauer, 2014). Compared to classical laboratory experiments, business management games have the advantage that a realistic decision-making environment can be simulated. This is particularly important, since the context can also have an influence on the decision-making behaviour (Levitt and List, 2009). In addition, internal validity can be increased by setting financial incentives, as is also common practice in laboratory experiments. In this way, participants make decisions under "familiar" environmental conditions that correspond to their true preferences (Hertwig and Ortmann, 2001).

Until now, it has not yet been examined whether nudging has the potential to steer behaviour in the case of enforcement of the minimum-distance-to-water rule. In this context, no experiment investigating the non-compliant behaviour of farmers has yet been conducted. It is unknown how nudging affects the probability of rule breaking and the severity of non-compliant behaviour. Against this background, the present study aims to elucidate the potential of nudges to increase compliant behaviour, using the example of the minimum-distance-to-water rule. Methodologically, a multi-period business management game is used, in which participants are confronted with different nudge treatments.

The remainder of this paper is structured as follows: Section 2 addresses relevant literature of behaviour-based regulation from which research hypotheses are derived. Section 3 outlines the design of the experiment. The collected data and the results are presented and discussed in section 4. The paper ends with a conclusion and an outline of future research prospects in section 5.

2. Derivation of Hypotheses

In a meta-analysis, Baumgart-Getz et al. (2012) investigate the implementation of best management practices by farmers, including the field of water conservation. It is pointed out that investment in human capital in the form of information provision can have a positive impact on the adoption of best practices. The knowledge gained from the information provision, can lead to a change of farmers' behaviour in this particular area. Further studies show that in the presentation of information, visual representations have a greater impact on human decision making than purely textual descriptions (Boer et al., 2006; Hollands and Marteau, 2013; Veer and Rank, 2012). Prominent examples are graphical warnings on cigarette boxes. The intention to stop or not even start smoking can be increased by images of health consequences of smoking (Noar et al., 2016). Sunstein (2014) lists graphical warnings as one of the ten most effective nudges in policy-making.

Abrahamse and Steg (2013) show in their meta-analysis how social influences can promote resource conservation in consumers. Information on how a group behaves can serve as a standard for other people. In addition, certain behaviour is adopted if similarities between the persons exist. Introduced by Festinger (1954), this social comparison theory was applied in the most influential work about nudging and energy consumption by Schultz et al. (2007). In their study, the authors conclude that a nudge with information on the neighbourhood's behaviour is effective at getting households to reduce their energy consumption. Similar findings were observed in the study by Allcott (2011). Ferraro and Price (2013) come to the result that residential water demand can be reduced by nudges which include social norms. Goldstein et al. (2008) find out that, with regard to the repeated use of towels in hotels, socially comparative feedback is more effective than providing only normative feedback. For farmers, Kuhfuss et al. (2016) also find that socially desirable behaviour is positively influenced by information about a social norm.

Against this background, the following research hypotheses are formulated:

H1. *Nudging with information and pictures about the consequences of non-compliant behaviour reduces…*

- ***a.*** *the probability of non-compliant behaviour*
- ***b.*** *the severity of non-compliant behaviour in the deviant subpopulation*

H2. *Nudging with information and pictures about the consequences of non-compliant behaviour and additional social information about other farmers' behaviour reduces…*

- ***a.*** *the probability of non-compliant behaviour*
- ***b.*** *the severity of non-compliant behaviour in the deviant subpopulation*

H3. *A nudge with additional social information about others' behaviour is more effective in encouraging compliant behaviour than providing the general information and pictures about the behaviour's consequences alone with regard to …*

- ***a.*** *the probability of non-compliant behaviour*
- ***b.*** *the severity of non-compliant behaviour in the deviant subpopulation*

Within the scope of the present investigation into the behavioural effects of different nudge treatments, the surveyed sociodemographic characteristics of the participants serve as control variables in a regression analysis.

3. Experimental Design

The overall study is structured as follows: First, socio-demographic characteristics of the participants are collected via a questionnaire. Subsequently, an extra-laboratory experiment (cf. Charness et al., 2013) is conducted in the form of a single-player multi-period business management game. Afterwards, the participant's risk attitude is determined by a Holt-and-Laury lottery (Holt and Laury, 2002). Moreover, the participants have to state their law-abiding attitude in a general sense on a Likert scale ranging from one to ten.

3.1. Experimental Assessment of Environmental Decision Behaviour

In the business management game, the participant is asked to manage a virtual farm over eight production periods. The farm consists of 15 ha of arable land subdivided into five fields, of which four are adjacent to a body of water (see Figure 1). At the beginning, participants are provided with an initial amount of 20,000 €. In each period, participants receive a transfer payment of 300 € per hectare. If financial difficulties occurred, the participant could borrow additional capital, which is automatically repaid at the end of a period if liquid funds become available again. For simplification, an interest rate of 0 % is assumed. This rule was established in order to prevent attrition of participants due to insolvencies.

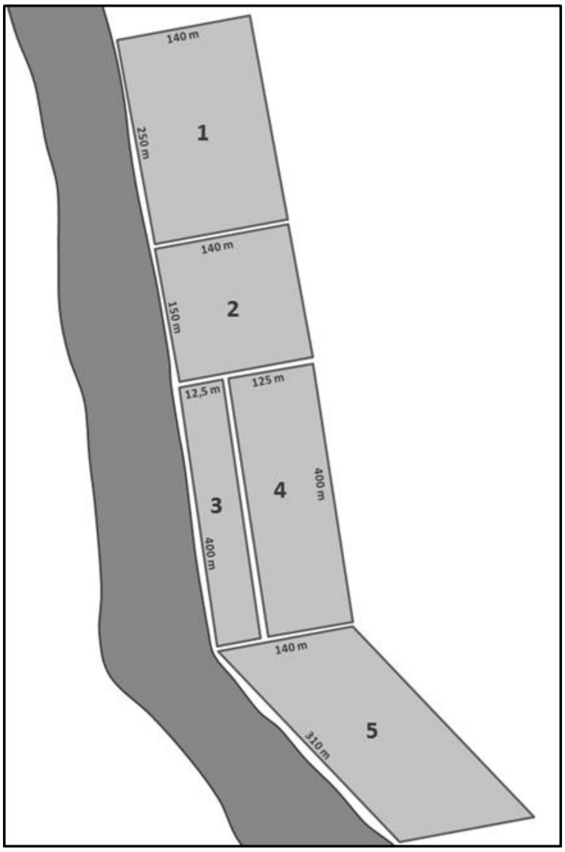

Figure 1: Arable land in the business management game

In each period, the participants have to make three kinds of decisions for each of the five fields:

1) Production program: Participants choose between the cultivation of grain maize, wheat or canola for each field. A restriction exists that each crop has to be cultivated at least once in a period.
2) Fertiliser intensity: The amount of fertiliser application for each field has to be determined. The value is given in 1 kg per ha steps.

3) Distance to water: The participant has to state the distance to the water which kept while applying fertiliser. Here, values can be entered by 0.1 metre steps.

The third variable "distance to water" offers an economic incentive to select a short distance, as the use of fertiliser leads not only to a higher yield, but also to higher revenue. At the same time, however, there is the minimum-distance regulation of three meters. This trade-off between profit and regulatory compliance exists over the entire duration of the business management game. To make the game even more realistic, and to obfuscate the objective of controlling for non-compliant behaviour, deterministic and stochastic parameters are introduced.

3.1.1. Deterministic Parameters

Several fields are threatened by drought stress, which reduces the expected crop yields by up to 20 %. The absolute reduction in yield due to drought stress depends on the fertiliser intensity and the drought index. Table 1 describes the production costs (cf. KTBL, 2016) as well as the fertiliser and drought-dependent production functions. Quadratic production functions and variable production costs are equal for all participants over the entire periods. The same applies to the nitrogen costs of 60 cents per kg. The areas to be managed in the business management game are presumably owned by the entrepreneur.

Table 1: Production function and variable production costs in the business management game

Crop	**Production function (q = yield in dt/ha, x = amount of nitrogen fertiliser in kg/ha)**	**Variable production costs (in €/ha) without fertiliser costs**	**Drought stress index (z)**
Grain Maize	$q_M = (91 + 0.5x - 0.001x^2) \cdot z$	950	$z = \begin{cases} 1, \text{for } i = 2, 3 \\ 0.9, \text{for } i = 1, 5 \\ 0.8, \text{for } i = 4 \end{cases}$
Wheat	$q_W = (48 + 0.5x - 0.001x^2) \cdot z$	800	
Canola	$q_C = (28 + 0.18x - 0.0004x^2) \cdot z$	820	*(i =number of field)*

3.1.2. Stochastic Parameters

All harvested crops are sold at the end of the respective period, and it is assumed that no storage option exists. To model a more realistic situation and add excitement for players, the product prices are volatile and vary among participants. At the beginning, prices are fixed with 16 €/dt for grain maize, 18 €/dt for wheat and 33 €/dt for canola. With a probability of 50 %, the product prices either increase or decrease by 10 % in the following period (see Figure 2). For simplicity, there is no correlation between crop prices. The sum of the profits gained in every production period resembles the total profit in the business management game.

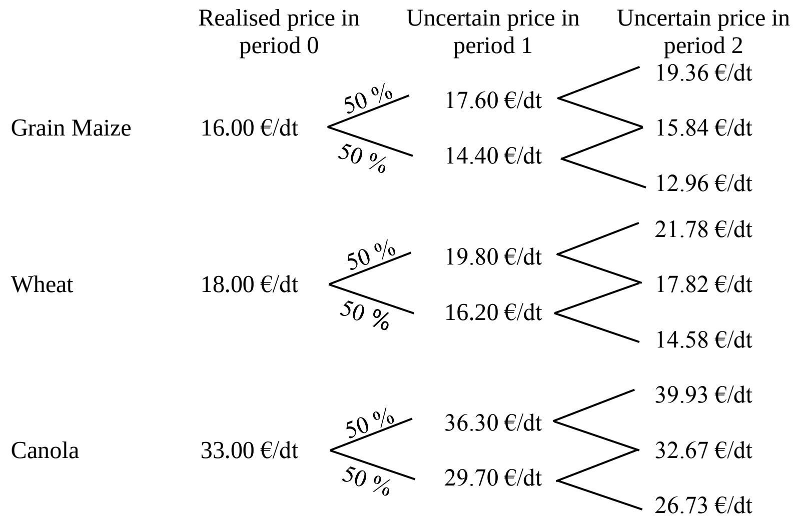

Figure 2: Development of product prices in the business management game[a]

[a] Participants see only actual and past product prices of the respective period

3.1.3. Treatments

At the beginning of the business management game, participants are randomly assigned to one of three groups. In the first four periods, the framework remains unchanged. In the last four periods, conditions stay the same only for the first group, the control group. Whereas group A and B receive a distinct nudge message according to their assigned treatment:

Treatment A (Group A): Participants are provided with information about the consequences of non-compliant behaviour regarding the minimum-distance rule, i.e. the environmental and health effects that may occur as a consequence of fertiliser inputs into bodies of water. This information is supported by pictures of a dead fish, a crying baby, and fertiliser which has been placed illegally on a buffer strip.

Treatment B (Group B): As in treatment A, participants are nudged with information and pictures as described above, but with an additional social comparison. In the supporting text provided, it is emphasized that colleagues in the same region, and especially at the neighbouring fields, comply with the minimum-distance regulation.

3.2. Elicitation of Individual Risk Attitude

The participant's risk attitude is quantified by the utilisation of a Holt-and-Laury lottery (Holt and Laury, 2002). This multiple price list method was chosen because it represents the "golden standard" of applied elicitation methods in the field of risk attitude measurement (Anderson and Mellor, 2009). It is also well established in agricultural economics (Hellerstein et al., 2013; Maart-Noelck and Mußhoff, 2014; Nielsen et al., 2013). The design of the lottery is based on the original Holt-and-Laury lottery. In ten decision situations, the participant has to choose between two lotteries (lottery A or B). In the safer lottery A, prize money of either 20 € or 16 € is distributed, whereas in the riskier lottery B one could gain either 38.50 € or 1 €. The probability of winning one of the two available prizes in a particular lottery is altered in every decision situation by 10 %, starting with a 10 % probability of winning the higher amount and a 90 % probability of receiving the lower amount. With increased probability, the expected values increase as well. In situation one to four, expected values in lottery A are higher. From situation five on, lottery B becomes the option with a higher expected value compared to lottery A. For a better understanding of the task, and therefore reducing inconsistent results, expected values are presented in both lotteries. Even though Hermann and Mußhoff (2017) show that displaying expected values has no influence on task comprehension of a standard subject pool, our study deals with farmers which represent a non-standard subject pool.

3.3. Incentive System

Every participant receives an Amazon gift voucher of 30 € as an incentive for the complete processing of the study. One convention of experimental economics is to provide financial incentives for participants for carefully considered decisions (Guala, 2005). Financial incentives are also set here in such a way that a trade-off is created between profit and compliant behaviour, which ensures that the participants reveal their true preferences. Experiments involving socially undesirable and non-compliant behaviour in particular can cause distortions if participants can behave free of charge in a socially desirable way (Milfont, 2009; Norwood and Lusk, 2011). In the business management game, prize money is awarded according to the participants earned profits. Participants are informed that

10 % of the participants will be randomly drawn. The winners will receive 100 € for every 100,000 € of total profit generated in the business management game.

In the lottery task, which consists of ten decision situations, every fifteenth participant is randomly chosen. A decision situation is selected by the first roll of a ten-sided dice for every winner. The second roll of this dice determines the amount paid out according to the decision of the participant for the respective lottery. Prize money between 1 € and 38.50 € can be won due to the lottery design.

4. Results and Discussion

4.1. Descriptive Results

The study was conducted online in November and December 2016 with German farmers. Participants were acquired via mail. The sample comprises 163 farmers whose socio-demographic and socio-economic characteristics are summarised in Table 2. The farmers in the sample are on average 39 years old with an age range of 17 to 70 years. The proportion of women is 7 %. The average household size is four members, including the participant. In the average farmer household, one person younger than 18 years lives there. 69 % are members of an association with a predominantly agricultural or environmental background. The average length of education is 14 years. 61 % of the participants have completed agricultural training. 59 % have a university degree. The share of farm managers is 66 %. For 77 % of the farmers, farm income represents the main source of income. The average farm size is 182 ha. Farm size varies from 6 to 2,400 ha. The farm types are mainly cash crops (35 %) or mixed farming (27 %). The self-assessed operating profit of "own farm" compared to "other farms" is on average 70 out of possible 100 points. Farm succession has already been arranged or the farms have been recently taken over in 71 % of all cases. Organic farms represent 14 % of the sample. According to the Holt-and-Laury Lottery, more than half of the participants (52 %) are risk-averse, 37 % are risk-neutral, whereas only 11% of the participants are risk seekers. In addition, 77 % of the farmers generally consider themselves more law-abiding, while 17 % say they are neither particularly law-abiding nor not law-abiding. 7 % of the participants do not see themselves as rather law-abiding.

Table 2: Socio-demographic and farm characteristics

	Total (n=163)	Control group (n=57)	Nudge treatment A: Information with pictures (n=53)	Nudge treatment B: Information with pictures and social comparison (n=53)
	Mean (Standard deviation)	Mean (Standard deviation)	Mean (Standard deviation)	Mean (Standard deviation)
Age in years	38.6 (12.0)	36.2 (11.9)	40.0 (12.0)	39.6 (11.8)
Share of female participants	7.4 %	5.3 %	7.6 %	9.4 %
Number of household members	3.8 (1.4)	3.8 (1.4)	3.8 (1.4)	3.7 (1.7)
Number of household members younger than 18 years	0.8 (1.1)	0.7 (1.1)	0.9 (1.2)	0.7 (1.1)
Share of participants being a member of an association	69.3 %	73.7 %	64.2 %	69.8 %
Years of education	14.4 (3.4)	14.2 (3.3)	14.4 (3.5)	14.7 (3.3)
Share of participants with agricultural training	61.4 %	59.7 %	60.4 %	64.1 %
Share of participants with university degree	58.9 %	56.1 %	60.4 %	60.4 %
Share of farm manager	66.3 %	61.4 %	67.9 %	69.8 %
Farm income as mainstay	77.3 %	73.7 %	77.4 %	81.1 %
Share of cash crop farms	35.0 %	33.3 %	30.2 %	41.5 %
Share of organic farms	13.5 %	14.0 %	11.3 %	17.0 %
Farm land in ha	182.2 (302.9)	163.3 (180.7)	205.3 (449.0)	179.6 (211.2)
Self-assessed operating success of farm compared to others (0-100)	69.6 (15.8)	68.8 (17.2)	67.7 (14.2)	72.2 (15.2)
Share of farms where succession is arranged	70.6 %	72.0 %	62.3 %	77.3 %
Risk attitude (HLL-value)[a]	5.0 (1.6)	4.9 (1.7)	5.2 (1.5)	5.0 (1.7)
Self-assessed law-abiding behaviour[b]	7.4 (1.9)	7.4 (2.0)	7.2 (1.9)	7.5 (1.8)

[a] 1-3 = risk seeking, 4 = risk neutral, 5-9 = risk averse
[b] 0-4 = rather not law-abiding, 5 = neither nor, 6-10 = rather law-abiding

4.2. Regression Models

For model selection, the specific data structure has to be taken into account. On the one hand, the participants make decisions on distances to water and fertiliser use in eight game periods, which is represented through panel data. Other variables, such as age and gender of the participants, are constant over time. In addition to the metrically measured extent of non-compliant behaviour (illicitly fertilised acreage), the probability of compliance is of further interest.

In order to consider all these points, the evaluation is carried out using a “Generalized Additive Model for Location, Scale and Shape” (GAMLSS; see Rigby and Stasinopoulos, 2005). It has the advantage that the distribution function of the dependent variable does not have to depend on the exponential family. In addition, an individual random intercept can also be included in the model as an additive term. Besides the mean value, further distribution parameters such as the probability of zero can be modelled as fixed and random effects. To take into account the number of zeros of the dependent variable, a gamma distribution adjusted to zero is assumed as the distribution function. This so-called ZAGA model (Zero-Adjusted Gamma Distribution) consists of a mixed distribution with the mean value μ (mean size of acreage on which fertiliser was applied illicitly), and the probability of zero ν (probability of compliant behaviour, e.g. size of illicitly fertilised acreage equals zero). For a detailed description and application examples of the ZAGA model, we refer to Buchholz et al. (2016) and Tong et al. (2013). A convenient advantage of the ZAGA model is that the probability of compliance and the extent of non-compliance can be estimated simultaneously[1]. In our model, we consider the decisions of the participants in periods 1 to 8, all decisions before and after the treatment, in order to examine the effects of the policy treatments.

Two regression models are estimated. In the first model, a comparison with the control group is made. The second model investigates differences between the two policy treatments, whereby treatment A is used as a reference. Treatment dummies for checking hypotheses are included in the ZAGA models, as well as a period dummy to account for potential learning effects, and all socio-demographic and farm characteristics of the participants as depicted in Table 2. Thereby the variables “Number of Household Members under 18 Years”, “University Degree” and “Farm Manager” had to be excluded[2], as multicollinearity with other remaining variables in the data set was identified according to the

[1] We also estimated an alternative two-stage model for the probability of compliance as a Logit Model and the extent of non-compliance as a Generalized Linear Mixed Model (GLMM) with a random intercept to take into account the panel data structure. This estimation led to qualitatively comparable results.

[2] The variable “Number of Household Members under 18 Years“ correlates with “Number of Household Members“, “University Degree“ with “Years of Education“, and “Farm Manager” with “Age”. We preferred including continuous variables over dichotomous variables due to higher information content.

Variance Inflation Factor (Zuur et al., 2010). To control for economic temptation, we included a variable called "Price Index", which represents the average price of the three possible crops in a particular period.

4.3. Results and Discussion

Table 3 shows the results of the two regression models. Model I uses non-compliant behaviour of the control group in periods 5 to 8 as a reference to test hypotheses 1 and 2, whereas non-compliant behaviour of group A in periods 5 to 8 serves as a reference in Model II to test hypothesis 3. The upper part of Table 3 depicts the probability of compliant behaviour. The severity of non-compliance in the deviant subpopulation is shown in the lower part.

Comparing the control groups behaviour in the last four periods with the behaviour in the first four periods we only find a small learning effect (4.5 % higher probability of compliant behaviour in periods 1 to 4; p-value = 0.900). Considering all groups, the estimated effect in the periods 1 to 8 is quite small (per period -1.3 % in probability of compliance with a p-value of 0.859. Against this background, we abstract from learning effects.

The estimated probability of compliant behaviour in group A (nudge with pictures) is increased by a factor of 3.1 (p-value < 0.001), compared to the control group (see model I, upper part of Table 3). In group B (nudge with pictures and social comparison), the estimated factor is 2.6 (p-value = 0.002). This represents strong evidence in favour of hypothesis 1a ("nudge with pictures reduces the probability of non-compliance") and hypothesis 2a ("nudge with pictures and social comparison reduces the probability of non-compliance"). In brief, both nudge types are effective.

In the deviant subpopulation (see model I, lower part of Table 3), we find that nudge A slightly decreases non-compliance (-5.6 %). Surprisingly, nudge B even increases non-compliance (+8.6 %). But both effects are relatively small and have high associated p-values (0.427 and 0.271, respectively). The evidence thus remains inconclusive, and the question of whether different nudges reduce the severity of non-compliance (hypotheses 1b and 2b) must be left to further studies.

The ZAGA model II allows for a comparison of treatment A with treatment B. The lower estimated effectiveness in model I of nudge B compared with A (2.6 times increase vs. 3.1 times increase in compliance) regarding the probability of compliance is reflected here. Compared to treatment A (nudge with pictures), the estimated effectiveness of treatment B (nudge with pictures and social comparison) is only 84.1 % (p-value = 0.639). This corresponds to the ratio of their two effect factors to the control group (2.6:3.1). The lower effectiveness of B is counterintuitive, and contradicts hypothesis 3a ("a nudge with pictures and social comparison is more effective than a nudge with images alone with regard to the probability of non-compliance"). In the deviant subpopulation, we find a similarly counterintuitive result. Compared to nudge A, the severity of non-compliance is increased by 15.1 % (p-value = 0.120) through nudge B. This contradicts hypothesis 3b ("nudging with additional social comparison is more effective with regard to the severity of non-compliance in the deviant subpopulation").

Table 3: Results of the ZAGA models (n=1,304)

	ZAGA model I (comparison with control group periods 5-8)			**ZAGA model II (comparison with nudge treatment A periods 5-8)**		
	Coefficient	Exp (coefficient)	p-value	Coefficient	Exp (coefficient)	p-value
logit (ν): Probability of compliance						
Intercept	-1.418	0.242	0.198	-0.289	0.749	0.797
Dummy period 1-4	0.044	1.045	0.900	-1.085	0.338	0.007
Dummy control group 5-8	-	-	-	-1.129	0.323	<0.001
Dummy nudge treatment A 5-8	1.129	3.092	<0.001	-	-	-
Dummy nudge treatment B 5-8	0.956	2.602	0.002	-0.173	0.841	0.639
Age	0.040	1.041	<0.001	0.040	1.041	<0.001
Gender	-0.627	0.534	0.061	-0.627	0.534	0.061
Household members	-0.009	0.991	0.873	-0.009	0.991	0.873
Association member	-0.570	0.566	0.006	-0.570	0.566	0.006
Agricultural training	0.901	2.461	<0.001	0.901	2.461	<0.001
Years of education	0.027	1.027	0.378	0.027	1.027	0.378
Farm type (part time/full time)	0.686	1.986	0.002	0.686	1.986	0.002
Cash crop farming	1.896	6.657	<0.001	1.896	6.657	<0.001
Cultivation type (conventional/organic)	0.854	2.349	<0.001	0.854	2.349	<0.001
Farm size	-0.001	0.999	0.012	-0.001	0.999	0.012
Self-assessed farm operating success	-0.007	0.993	0.237	-0.007	0.993	0.237
Farm succession	0.090	1.094	0.637	0.090	1.094	0.637
Risk attitude (HLL-value)	0.302	1.352	<0.001	0.302	1.352	<0.001
Self-assessed law-abiding behaviour	0.062	1.064	0.138	0.062	1.064	0.138
Price index	-0.058	0.943	0.038	-0.058	0.943	0.038
Period	-0.013	0.987	0.859	-0.013	0.987	0.859
log (μ): Severity of non-compliance in deviant subpopulation						
Intercept	7.516	1,837.792	<0.001	7.458	1,733.972	<0.001
Dummy period 1-4	0.025	1.025	0.577	0.083	1.087	0.219
Dummy control group 5-8	-	-	-	0.058	1.060	0.427
Dummy nudge treatment A 5-8	-0.058	0.944	0.427	-	-	-
Dummy nudge treatment B 5-8	0.082	1.086	0.271	0.141	1.151	0.120

The concrete results of the experiment can be summarised as follows: First, both nudges had a preventive effect in the experiment, and considerably reduced the share of non-compliant experimental subjects. Second, nudge B with pictures and social comparison had, against initial expectation, a weaker preventive effect than the nudge A with pictures. Third, it seems that the effect of nudging differs in different subpopulations. Both nudges were effective as a preventive measure overall; but within the deviant subpopulation, the effects of the two nudges were ambiguous. While nudge A slightly reduced the severity of non-compliance, even the reverse occurred in the case of nudge B.

Currently, we can only speculate about the reasons of the second and third outcome. One reason could be reactance (Brehm and Brehm, 1981; Miron and Brehm, 2006). Reactance describes an individual's internal resistance or defiance that arises when an external attempt at influencing is perceived as illegitimate. The nudges may have triggered such a reaction and produced a perverse effect within the group of deviant participants who may have felt that "illegitimate" means had been used to urge them to comply with "illegitimate" rules they did not accept in the first place (missing value correspondence between regulators and regulates; cf. Hirschauer and Zwoll, 2008). In other words, especially the "high-intensity" nudge B may have instigated non-responsive participants to break the rules in order to reclaim what they considered their legitimate freedom of action. Another speculative reason for the lower effectiveness of the nudge with social comparison could be the free-rider problem (Olson, 1965). This means that participants believe that their individual contribution to environmental pollution is marginal and that, in the end, the selfish violation of the rule will hardly lead to any negative externalities if the majority complies.

It is remarkable that agricultural training has a positive effect on the probability of compliance (increase by a factor of 2.5 with a p-value < 0.001). Practical education increases the adaptation of best management practices by farmers (Baumgart-Getz et al., 2012), which is tantamount to compliance with regulation. If we consider compliance in the case of the minimum distance rule not only as following a rule, but being concerned about the environment, our results coincide with the findings of Baur et al. (2016) that environmental consciousness increases with age. Furthermore, the probability of compliance is increased by a factor of 2.3 (p-value < 0.001) for organic farms compared to conventional farms. This is justified by the fact that organic farmers are considered to be more environmentally conscious than their conventional colleagues (Läpple, 2013). Compliance behaviour of cash-crop farmers increases by a factor of 6.7 (p-value < 0.001) compared to farmers not specialised in cash-crop farming. Since the minimum-distance regulation is particularly important for this type of farm, these farmers may be more compliant. The same applies to full time farmers as opposed to part time farmers, where compliance increases by a factor of 2.0 (p-value = 0.002). Farmer's risk attitude is another factor that affects compliance behaviour. The more risk averse a farmer, the higher the probability to comply. Similar evidence was found in studies related to non-compliant behaviour of taxpayers (Ghosh and Crain, 1995; Trivedi et al., 2003). We can only speculate why membership in a farming association is negatively related to compliance (-43.4 %, p-value = 0.006). While communities and peers exercise influence on individual behaviour (Siddiki et al., 2012; Sutinen and Kuperan, 1999), it is astonishing that a respected business association does not exercise social control on its members to comply with regulations. The contrary seems to be the case. In addition, farm size is negatively related to compliance: With an increase by one hectare, the probability of a rule violation rises by 0.1 % (p-value = 0.012). Increasing product prices constitute another factor in reducing compliant behaviour. In the business management game, compliant behaviour is reduced by 5.7 % (p-value = 0.038) with every Euro increase in average product prices. This is plausible because rising product prices increase the profit trade-off that a farmer needs to accept in exchange of complying with the restrictive fertilising rules.

5. Conclusions and Outlook

The present experimental study with farmers investigated the preventive effect of two green nudges on compliance with the minimum distance regulation for fertilisation close to a body of water. Nudge A was based on information with pictures of the negative environmental impacts of a rule violation. In the case of nudge B, it was additionally pointed out that other farmers behave in accordance with these rules. Both green nudges were effective as preventive measures and reduced the share of non-compliant subjects. Contrary to previous expectations, a nudge with additional social comparison had no stronger effect than a simple nudge with pictures. In addition, there was a divergent effect of the nudges. In the deviant, non-responsive subpopulation, only nudge A reduced the severity of rule violations, while nudge B even increased the severity of non-compliance.

Reactance could be a plausible explanation for the differing effects in the subpopulation. If the fairness concepts of those afflicted by the regulation and the regulator strongly diverge, and the former perceive the distance regulation as illegitimate, a nudge might be ineffective or even counterproductive. Potential opposite effect of the same policy measure on different parts of the targeted social group appears to be an essential and important subject of future research. One question to be addressed is whether the opposite effect of nudges is stable in responsive and non-responsive groups, and what differences exist in other regulatory subjects and social contexts. The exploratory analysis of the control variables provided evidence that for example, older farmers as well as more risk-averse farmers tend to be more compliant. A deeper understanding of how these and other characteristics might have implications for policy design and implementation could be investigated in follow-up studies. A further question arises as whether or how positive nudge effects can be maintained and at the same time, possible negative effects can be contained or avoided. In other words, how can the justice concept of the regulator and the policy subjects be better harmonised, in order to avoid reactance in small subpopulations when adopting regulatory regulations and supportive nudge measures?

In addition to reactance, other explanatory approaches of (non-) compliance as well as the different and partly counterproductive effect of the nudges should be investigated. It would be interesting to find out to what extent so-called stable individual personality traits (e.g. the Big Five; see Costa and McCrae, 1992) exert an influence on the behavioural effects of nudges. It could also be investigated whether perceived control over one's own behaviour plays a role in violations of regulations (e.g. the theory of planned behaviour; see Fishbein and Ajzen, 1975, 2010). The analysis of the behavioural effects of social norms and protective factors that prevent actors from giving in to material temptations (Hirschauer and Scheerer, 2014; Lösel and Bender, 2003), could also be part of future research to explain compliance behaviour.

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