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TAX OR GREEN NUDGE?
AN EXPERIMENTAL ANALYSIS OF PESTICIDE POLICIES IN
GERMANY

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Abstract

Pesticides are an important input in modern agriculture. However, intensive use of pesticides is also related to adverse effects on the environment and human health. While implementation of pesticide taxes with the intent to reduce pesticide applications has been widely discussed, green nudges are considered as innovative policy tools to foster environmental friendly behaviour. To date, little is known about the effects of these policy tools at the farm level. With this in mind, we use a business management game to investigate how a pesticide tax and a green nudge affect crop, tillage and pesticide decisions for a ‘virtual’ farm. Results from a sample of German agricultural students reveal that both policies are able to reduce the amount of pesticides applied. However, implementation of the pesticide tax also involves a substantial profit loss. Unlike in the green nudge treatment, participants under pesticide tax adjust their cropping and tillage strategies which could involve unintended ecological effects.

Keywords

Pesticide tax, green nudge, ex ante policy impact analysis, business management game.

1 Introduction

Crop protection aims to prevent or reduce crop losses that can result from harmful pests such as weeds and pathogens (Oerke, 2006). Among other technologies, the application of pesticides has contributed considerably to the boost in agricultural productivity in recent decades (Sexton et al., 2007). Cooper and Dobson (2007) summarise the many benefits that arise from pesticides in agricultural production. On the contrary, an excessive and inappropriate use of pesticides could also lead to negative external effects for the society that could, for example, be related to the contamination of ground and surface water, degradation of ecosystems and biodiversity, human health, food safety, and the evolution of pest resistance (Pimentel et al., 1992). Reducing the harmful effects and risks from pesticides on the environment and human health has become a common policy objective in many countries (Skevas et al., 2012). There is a broad set of policy options that could be designed to reduce pesticide use (Oskam et al. 1997).

Economic instruments have become increasingly popular among policy makers and are applied to change farmers’ behaviour by setting financial incentives (Vries and Hanley, 2016). In the light of the National Action Plans implemented in the European Union, there has been growing interest with respect to pesticide taxes in European countries. In a recent review, Böcker and Finger (2016) report that pesticide taxes are currently applied in Denmark, France, Norway, and Sweden while the implementation is also discussed in other countries, such as Germany or the Netherlands. Thus far, empirical evidence on the effectiveness of pesticide taxes is mixed. Some authors advocate the implementation of pesticide taxes arguing in the sense of the polluter pays principle (Oskam et al., 1997). Finger et al. (2017) state that differentiated and well-defined pesticide taxes have a high potential to reduce risks from pesticide applications. However, they also note that pesticide taxes are ineffective in the short-run due to hoarding activities. Furthermore, the magnitude of the tax needs to be high which requires a re-distribution of tax revenues to the agricultural sector to prevent considerable income effects. An additional strand of research argues that farmers’ demand for pesticides is rather inelastic, and thus, hampering the effectiveness of taxation schemes (Böcker and Finger, 2016; Skevas et al., 2012). For example, in Sweden and Denmark the introduction of a pesticide tax has not led to a substantial decline in pesticide sales and pesticides applications in absolute terms (SCB, 2017; Pedersen et al., 2015). Moreover, a solid ex post evaluation that controls for confounding effects, such as changes in

cereal prices, is usually lacking. It is not clear how pesticide applications would have developed without the implementation of taxes (Pedersen and Nielsen, 2017).

During the last decade, a new policy tool has captured the attention of policy makers. In addition to traditional policy tools, behavioural interventions in the form of nudging are increasingly being considered in different public policy contexts. According to Thaler and Sunstein (2008), a nudge is “any aspect of choice architecture that alters behavior in a predictable way without forbidding alternatives or significantly changing economic incentives” (Thaler and Sunstein, 2008 p. 8). Nudging takes advantage of various psychological biases in decision-making, such as inertia (Samuelson and Zeckhauser, 1988) or loss aversion (Kahneman et al., 1991), and can be implemented in wide variety of ways (Sunstein, 2014). Besides the provision of information (e.g. emphasising health consequences of smoking stated on cigarette boxes, cf. Hammond et al., 2006), the change of default options (e.g. changing the default setting of printers, from single-sided to double-sided printing, cf. Egebark and Ekström, 2016) or the use of social norms (e.g. comparing personal energy consumption to neighbours, cf. Allcott, 2011), the utilisation of priming is also part of the nudge toolkit. Priming is defined as the mental process by which the exposure to a stimulus, in other words a prime (e.g. words or images), activates associations in memory and thereby unconsciously influences a person’s behaviour (Kahneman, 2011). Priming with colours is seen as particularly effective because people are exposed to colour in everyday life (Elliot et al., 2007). The colour red is most commonly associated with danger and risk as it is used to denote warnings or threats (e.g. warning signs or traffic light). Compared with complex information, the simplified depiction of information in the form of a traffic light is easier to understand (Olstad et al., 2015).

Nudging has become a popular policy tool in various domains, such as health economics (Arno and Thomas, 2016), tax compliance (Bobek et al., 2007) or environmental protection (Sunstein and Reisch, 2014). Recently, nudging is not only implemented to improve the welfare of the individual but also to reduce negative externalities in terms of environmental pollution, which is also referred to as green nudging (Schubert, 2017; Carlsson et al., 2018). The increasing interest in nudging raises the question if such behavioural interventions could also be implemented in an agri-environmental context to reduce negative external effects of agricultural production. So far, only a few studies have examined the effects of nudges in an agricultural setting. Chabé-Ferret et al. (2018) analyse a social comparison nudge on the water-saving behaviour of French farmers. On average, nudging does not contribute to a change of water consumption patterns. However, they find that a nudge may increase water consumption of low level water users and decrease consumption of high level users. Peth et al. (2018) found that a nudge with information and pictures, as well as a nudge with an additional social comparison, can lead to an overall increase in compliance with water protection rules for German farmers. Nevertheless, the authors point out that nudging in conjunction with a social comparison may aggravate already existing non-compliant behaviour. Kuhfuss et al. (2015) show that by the usage of social norms in nudging, French farmers can be persuaded to participate in an agri-environmental scheme or continue participation in a scheme that has already begun. Czap et al. (2015) reveal that empathy nudges can strengthen environmental friendly behaviour of US farmers by the appeal to put oneself in the shoes of a person who is affected by environmental pollution. Furthermore, Barnes et al. (2013) note that social comparison nudging may lead to higher adoption rates of water quality management techniques on farms in Scotland.

Analysing the impact of agri-environmental policies, such as pesticide taxes or green nudging schemes prior to its implementation (*ex ante*), and how farmers might respond to these policies is a challenging task. Thorough *ex ante* policy analysis is beneficial for the society as it can prevent budgetary costs or unintended consequences from ill-designed policies. Existing studies dealing with *ex ante* impact assessment of agri-environmental policies predominately rely on

normative rational choice models that are subject to rather restrictive assumptions, such as profit-maximizing behaviour (Gsottbauer and van den Bergh, 2011). However, there is evidence that decision makers in general – and farmers in particular – neither exhibit profit-maximizing behaviour nor act completely in accordance with the expected utility theory (Tversky and Kahneman, 1992). Likewise, decision makers could pursue multiple goals beyond profit-maximization and risk mitigation (Benz, 2009). Moreover, farmers' decisions could be prone to bounded rationality (Simon, 1990). In addition, individual goals, attitudes and values may vary substantially among farmers (Maybery et al., 2005). As a consequence, farmers might respond differently to the same policies and in another way than predicted by normative forecasts.

Recently, the application of so-called business management games for an experimental *ex ante* analysis of agri-environmental policies has been established (Mußhoff and Hirschauer, 2014). Business management games can be classified as extra laboratory experiments (Charness et al., 2013). In business management games, participants deal with entrepreneurial decisions within a controlled environment framed to reflect complexities that are as realistic as required to address the particular research question (Keys and Wolfe, 1990). Costs can be kept low compared to field experiments (Burtless, 1995). Several studies have used business management games for agricultural policy impact assessments. Holst et al. (2014) evaluate reward and penalty policies to foster the growing of flowering cover crops. Dörschner and Mußhoff (2015) analyse farmers' environmental protection behaviour using species richness as an example. Buchholz et al. (2016) investigate different policy instruments for reducing irrigation water, Hermann et al. (2017) study policy options to enhance carbon sequestration in agricultural soils, and Peth et al. (2018) compare the effects of different nudge interventions on farmers' compliance behaviour with water protection rules.

Although the implementation of pesticide taxes has been widely discussed, there is only limited evidence on how individual farmers might respond at the farm-level (Skevas et al., 2012). To the best of our knowledge there is no experimental analysis of pesticide taxes to reduce pesticide applications. Furthermore, there is limited evidence how green nudges can be applied in an agricultural context. In particular, the concept of nudging as a means to lower pesticide applications has not yet been applied. Moreover, only a few studies compare the effects of taxes and nudges (Goldin and Lawson, 2016; Galle, 2014). Hence, there is still a need for empirical studies directly comparing the performance of nudge interventions with other types of policy instruments (Benartzi et al., 2017). Against this background, we seek to address the following research questions:

- (1) Does the enforcement of a pesticide tax affect pesticide applications?
- (2) Can nudging be applied to reduce pesticide applications?
- (3) Which intervention is more effective in reducing pesticide applications – a tax or a nudge?

In order to analyse and compare the effects of a pesticide tax and a green nudge, we conduct an incentivised multi-period business management game with German agricultural students in which participants make production decisions, including the application of pesticides. Our approach is not confined by rational choice assumptions. In an analysis of agri-environmental measures, Peth and Mußhoff (2018) compare decisions from students and farmers in a business management game. Their results show that the direction of the response to policy treatments was similar for agricultural students and farmers. Only the magnitude of the treatment effect differed between the two samples.

2. Experimental Design

Our experiment consists of two parts. First, we conducted an incentivized multi-period, one-person business management game. Secondly, socio-demographic characteristics of the participants were collected. Detailed experimental instructions are provided on request.

2.1. General Structure of the Business Management Game

In the business management game, participants managed a virtual cash crop farm with 200 hectares (ha) of arable land. The game design is simple and easy for the participant to follow, yet complex enough to answer our research questions. Participants have to manage the farm for ten production periods. At the beginning of each period, three production decisions have to be made:

- (1) Crop plan: All 200 ha of the arable land must be allocated to some combination of winter wheat and silage maize. In accordance with good agricultural practices, the shares of winter wheat and silage maize in each period are constrained to 140 ha (70 %) or less in each case.
- (2) Tillage strategy: For each crop, participants can use conventional or conservation tillage.
- (3) Pesticide strategy: For each crop, participants can choose from three pesticide intensities.

Once the decisions have been made, the actual pesticide application rates are subject to environmental conditions occurring in the production period. To reduce game complexity, we assume simultaneous choice of crop and tillage plans as well as the pesticide strategy.

Crop yields are derived from comprehensive long-term field trials which were carried out in Germany (Pallutt et al., 2010; Jahn et al., 2010; LfL, several years). These field trials investigate the consequences of reduced pesticide applications using three different pesticide intensities: Local standard following situational extension advice (100 % pesticides), a selective reduction of the standard application rate by 25 % (75 % pesticides), and a blanket reduction of the standard application rate by 50 % (50 % pesticides). Pesticide treatments in the business management game are approximated by means of the so-called Treatment Frequency Index (TFI). In Germany, the TFI is used to quantify the intensity of chemical crop protection and comprises the number of pesticide treatments (fungicides, herbicides, insecticides and growth regulators) while considering the actual pesticide dosage relative to the maximum permitted dosage and treated area (Andert et al., 2015). For the 100 % pesticide strategy, TFI values are calibrated based on results from the ‘network reference farms plant and protection’ in Germany (Dachbrodt-Saaydeh et al., 2018) in order to reflect average farming conditions.

Crop yields are contingent on the chosen pesticide and tillage strategies. As the need for pesticide treatments might vary considerably according to the actual infestation of weeds and pathogens, we define three environmental states corresponding to unfavourable, normal and favourable conditions. Meanwhile, participants do not know which specific environmental conditions are going to follow. However, they are aware that unfavourable conditions occur with a probability of 20 %, normal conditions with a probability of 60 %, and favourable conditions with a probability of 20 %. In general, winter wheat is more vulnerable to pests than silage maize and requires more pesticide treatments. Likewise, conservation tillage might facilitate proliferation of weeds in the long-run resulting in higher herbicide demands as compared to conventional tillage. Variable costs are based on reference calculations (KTBL, 2018). For the pesticide strategies with reduced pesticide intensity we assume additional costs of 10 €/ha for enhanced plant control and extension service.

In each production period, the manager of the virtual farm receives the total gross margin from crop production. A premium of 300 €/per hectare is assumed to cover the fixed costs of farming. Any remaining net profit is transferred to a virtual bank account. We assume that participants have access to interest-free loans for financing their variable costs in order to avoid insolvencies. All products are sold at the end of each production period at the current market price. It is not possible to store the harvested crops. Product price developments follow an arithmetic Brownian motion (Dixit and Pindyck, 1994, p.63) starting from an initial value that is equal for all participants. Product prices for winter wheat and silage maize are not correlated for

reasons of simplicity. After each period, participants receive a summary of the chosen crop plan, the realized profit, the realized TFI, the development of market prices, and the environmental conditions of the previous periods.

Before participants begin the business management game, control questions were provided to explicitly test if the participant had understood the instructions. These questions are designed in a way that correct answers are required in order to proceed. Before the actual business management game starts, participants have to pass a ‘trial round,’ which is not recorded but provides them an opportunity to become more familiar with the decision environment. These features improve the participant’s understanding.

2.2. Policy Framework (Treatments)

At the beginning of the business management game, participants are randomly assigned to one of three groups. Product price series and the development of the environmental conditions are identical for all participants and have been drawn in advance. This enables us to isolate the effects of the pesticide tax and the green nudge. In the first five production periods, the policy framework is identical for every participant. In the subsequent production periods (six through ten), the policy framework in the three groups becomes distinct:

Control group: The policy framework remains unchanged – no restriction on pesticide use – over the entire duration of the business management game.

Pesticide tax treatment: We inform participants assigned to this treatment that the state will impose an additional tax on pesticides. The tax payment depends on the level of pesticides applied and amounts to 25 € per index point of the TFI. For winter wheat a pesticide strategy following local standards (100 % pesticides) and under normal environmental conditions, variable costs increase by 137.5 €/ha for instance. The design of the pesticide tax is set to approximate the tax burden in a recent proposal for a pesticide tax in Germany (Möckel et al., 2015). For reasons of simplicity, the pesticide tax in the business management game solely depends on the applied amount of pesticides in absolute terms. Thus, we do not account for varying toxicity levels of specific pesticides.

Green nudge treatment: Participants in this treatment are informed that the state introduces new warning signs on plant protection products. All pesticides will be labelled with a traffic light depending on the toxicity level. In this business management game, the respective pesticide intensity is assigned to a traffic light colour for simplicity reasons (100 % = red, 75 % = yellow and 50 % = green).

2.3. Incentives for Well-Conceived Decisions

It is common practice to set incentives in economic experiments; former studies reveal that incentives generally improve decision making and result in better experimental findings (Guala, 2005). To enhance motivation, each of the expected 100 participants received a representation allowance of 10 € if they completed the experiment. The average time to finish the experiment was approximately 30 minutes. In addition to the representation allowance, we provided additional success-oriented cash prizes. Financial incentives were set in such a way that a trade-off was created between monetary objectives and socially desirable behaviour. Firstly, prize money was awarded corresponding to the profits generated by the participants in the business management game. At the beginning of the experiment, participants were informed that three per 100 participants would be randomly drawn and those selected would receive 10 € for every 10,000 € of the average profit generated in the business management game. The prize money awarded ranged from 77 € to 107 €. Rewarding the average profit is expected to balance pure risk-seeking and risk mitigation strategies, and should mitigate any loss of motivation that participants might feel after experiencing a low profit in early periods. Secondly, three per 100 participants had the chance to win a donation to a non-profit/charitable organization free of

choice. Participants knew that the amount of the donation depends on the applied amount of pesticides in the business management game. The participant who realized the lowest average TFI would have the chance to receive a donation of 100 €. The three actually selected winners received a share of 100 € corresponding to the realized TFI. Donations awarded ranged from 58 € to 77 €. By means of the donation to a non-profit/charitable organization, we reward pro-environmental behaviour in the business management game. Depending on the preferences of the participants, the price money and donation rewarded can motivate the pursuit of economic or environmental objectives and the use of mixed strategies.

3. Results

3.1. Participants and Descriptive Results

The experiment was conducted online from August to mid of November 2018 with a sample of German students. Participants were recruited among agricultural students at the University of Göttingen. The sample is comprised of 110 agricultural science students. On average, the participants are 23 years old, with ages ranging from 18 to 35 years. The proportion of male students is 67 %. The sample consists of 67 % Bachelor students and 33 % Master students. 40 % of the participants have completed an agricultural training programme. The majority of students (65 %) have a family farm background. According to the self-assessed risk attitude scale following Dohmen et al. (2011), participants are on average slightly risk-seeking.

Table 1a) shows the average farm-level TFI in the three groups in the business management game. We distinguish between periods 1-5 (before the treatment) and periods 6-10 (after the treatment). We first determine whether the TFI in the three groups is comparable before the treatment in periods 1-5. A Kruskal-Wallis test reveals a statistically significant difference in the average TFI between all groups in periods 1 to 5 ($p\text{-value} \leq 0.001$). This finding might indicate that there could be confounding effects from behavioural differences not evenly distributed across groups. If we take a look at the development of the farm-level TFI over periods, for all groups a small downward trend of the TFI in the course of the business management game is apparent. We need to bear these findings in mind when contrasting the average TFI in periods 1-5 and 6-10 (within-subject comparison) and across groups for periods 6-10 (between-subject comparison). By means of the within subject comparison we can account for different levels of the TFI between groups in periods 1-5. The between-subject comparison for periods 6-10 isolates possible effects from the downward trending TFI. In doing so, we are able to draw first conclusions about the effectiveness of the policy treatments.

For the control group, a Mann-Whitney-U test reveals no difference at the 5 % significance level in farm-level TFI between periods 1-5 and 6-10. In contrast, we observe a decline in the average TFI in the two groups with policy treatments in periods 6-10. In the pesticide tax treatment and nudge treatment, the TFIs in periods 6-10 are 0.58 and 0.29 index points lower corresponding to a relative decline by 16.91 % and 9.09 %, respectively. Both differences are statistically significant according to a Mann-Whitney-U test ($p\text{-values} \leq 0.001$).

The policy treatments might not only have an influence on the TFI but also on the crop plan and the tillage strategy. Therefore, we analyse the aggregated decisions of participants on crop choice and the share of conventional and conservation tillage (Table 1b). With regard to the selected crop acreages, we only see a slight but significant decrease in the average share of winter wheat in the pesticide tax group from periods 1-5 to periods 6-10 ($p\text{-value} \leq 0.008$). Since it is not allowed to set aside land in the business management game, the reduction of winter wheat by 5 percentage points corresponds to an increase in the shares of silage maize by 5 percentage points. In the nudge treatment, we do not find a comparable effect.

Table 1: Descriptive Results**a) Mean (standard deviation) of farm-level and crop-specific pesticide intensities (TFI) according to treatment group ^a**

Treatment group	Farm-level			Winter wheat			Silage maize		
	P 1-5	P 6-10	Dif.	P 1-5	P 6-10	Dif.	P 1-5	P 6-10	Dif.
Control	3.29 (0.67)	3.15 (0.74)	-0.14	4.60 (0.83)	4.45 (0.95)	-0.15	1.50 (0.47)	1.38 (0.42)	-0.12 ^b
Pesticide tax	3.43 (0.63)	2.85 (0.67)	-0.58 ^b	4.70 (0.81)	3.98 (0.80)	-0.72 ^b	1.60 (0.41)	1.36 (0.39)	-0.23 ^b
Green nudge	3.19 (0.65)	2.89 (0.68)	-0.29 ^b	4.45 (0.80)	4.06 (0.84)	-0.39 ^b	1.45 (0.41)	1.28 (0.33)	-0.17 ^b

b) Shares of aggregated crop and tillage choice according to treatment group (%) ^a

Treatment group	Winter wheat			Silage maize			Conventional tillage			Conservation tillage		
	P 1-5	P 6-10	Dif.	P 1-5	P 6-10	Dif.	P 1-5	P 6-10	Dif.	P 1-5	P 6-10	Dif.
Control	58.07	56.61	-1.46	41.93	43.39	1.46	52.78	58.74	5.96	47.22	41.26	-5.96
Pesticide tax	59.54	54.66	-4.88 ^b	40.46	45.34 ^b	4.88 ^b	58.04	70.58	12.54 ^b	41.96	29.42	-12.54 ^b
Green nudge	57.86	56.56	-1.30	42.14	43.44	1.30	62.63	62.39	-0.24	37.37	37.61	0.24

c) Mean and (standard deviation) of profit, revenue and variable costs in €/ha according to treatment group ^a

Treatment group	Profit			Revenue			Variable costs		
	P 1-5	P 6-10	Dif.	P 1-5	P 6-10	Dif.	P 1-5	P 6-10	Dif.
Control	519.98 (61.40)	499.89 (78.35)	-20.09 ^b	1,373.63 (77.64)	1,347.32 (92.84)	-26.31 ^b	853.65 (37.85)	847.42 (41.67)	-6.23
Pesticide tax	520.91 (62.51)	421.22 (82.71)	-99.68 ^b	1,384.72 (77.50)	1,329.51 (96.19)	-55.21 ^b	863.81 (34.49)	908.28 (55.69)	44.47 ^b
Green nudge	520.12 (61.68)	489.65 (83.31)	-30.47 ^b	1,371.63 (75.20)	1,328.21 (95.81)	-43.42 ^b	851.51 (36.51)	838.56 (41.72)	-13.00 ^b

^a N=110. Bold values indicate significant differences in between-subject comparison for periods 6-10, control group serves as baseline (p-value ≤ 0.05).

^b Significant difference in within-subject comparison before (periods 1-5) and after treatment (periods 6-10) (p-value ≤ 0.05).

Source: Own calculations.

According to a Kruskal-Wallis test, the share of conventional tillage differs significantly across groups in periods 1-5 before the treatment ($p\text{-value} \leq 0.001$) which might be an indicator for varying preferences regarding soil management practices. Most strikingly, we only find a significant increase (decrease) in the share of conventional tillage (reduced tillage) in the pesticide tax treatment group both in the within-sample ($p\text{-value} \leq 0.001$) and between-sample comparison ($p\text{-value} \leq 0.001$). Also, the share of conventional tillage (conservation tillage) in periods 6-10 is significantly higher (lower) in the pesticide treatment than under the green nudge ($p\text{-value} \leq 0.022$).

As product prices and environmental conditions are identical for all participants, the generated profits in the business management game reflect the economic consequences of the pesticide tax and the green nudge. Table 1c) reports average profits, revenues and variable costs according to treatment group for periods 1-5 and 6-10. In periods 1-5, there is almost no difference in profits between the three groups. In general, there is a slight and significant decline in revenues from period 1-5 to 6-10 in all groups. While the introduction of the pesticide tax leads to a decline of the average profit by 99.68 €/ha ($p\text{-value} \leq 0.001$) profits in the nudge treatment group decrease by 30.47 €/ha in periods 6-10 ($p\text{-value} \leq 0.001$). According to the between-subject comparison in periods 6-10, profits in the pesticide tax group and green nudge group are on average 78.67 €/ha and 10.24 €/ha lower than in the control group, respectively. However, only the difference for the pesticide tax is significant ($p\text{-value} \leq 0.001$). On average, profits in the green nudge treatment are 68.43 €/ha above those generated under pesticide tax ($p\text{-value} \leq 0.001$).

3.2. Approach to Data Analysis and Results of the Regression Models

The participants' decisions regarding pesticide intensity are recorded as TFI for every period of the business management game. We apply an econometric model to control for the influence of single parameters in the business management game and other covariates of the questionnaire on pesticide application. In doing so, we can separate confounding effects, such as learning effects during the experiment. The data set contains longitudinal data due to the recurring decisions made by individual participants, which can vary over the ten periods of the business management game. The questionnaires also provide time-invariant sociodemographic characteristics. Moreover, the dependent variable TFI is confined to positive real values ranging from 1.31 to 5.22, depending on the decisions and environmental conditions in the business management game. A Shapiro-Wilk test indicates that the TFI is not normally distributed ($p\text{-value} < 0.001$). To address these issues, we make use of the generalized additive models for location, scale and shape environment (GAMLSS). GAMLSS is a very general class of (semiparametric) regression models proposed by Rigby and Stasinopoulos (2005). GAMLSS features a large variety of response distributions for the dependent variable. Moreover, individual random intercepts can be incorporated as additive terms.

Table 2 shows the results of two regression models. In line with the within-subject comparisons, model I uses the farm-level TFI in periods 1 to 5 (before the treatment) as a reference, whereas the farm-level TFI of the control group in periods 6 to 10 is the reference in model II (between-subject comparison). In addition to the variables from the business management game, such as product prices and environmental conditions, socio-demographic characteristics of the participants and dummy variables corresponding to the policy treatments are possible covariates. Variable selection is done by means of a search routine providing the best model fit according to the Akaike Information Criterion (AIC). The routine identified dummy variables for the two policy treatments (pesticide tax and green nudge), a dummy for favourable weather conditions, the product price for winter wheat and a dummy variable which refers to the periods in the business management game. For the final models, we manually incorporate additional socio-demographic variables to test whether there is an impact on TFI. For model I, we add a dummy for the control group to test if there is an effect on TFI without policy interventions in periods 6-10.

Estimates in Table 2 are presented as (exponentiated) logs. The results of model I reveal that the enforcement of the pesticide tax and green nudge reduce the TFI by 10.5 % ($1/0.895-1$) and 4.2 % ($1/0.958-1$), respectively, compared to periods 1-5 before the treatments are applied. While the effects are statistically significant for the pesticide tax ($p\text{-values} \leq 0.001$) and green nudge ($p\text{-values} = 0.023$) treatment, it is not the case in the control group. According to model II using decisions from the control group in periods 6-10 as reference, the TFI is reduced by 6.9 % in the pesticide tax treatment ($p\text{-value} \leq 0.001$) and by 7.1 % in the green nudge treatment ($p\text{-value} \leq 0.001$). Both models represent strong evidence that the policy treatments were effective in reducing the TFI. As the results for both models coincide, we are also able to rule out adverse effects from learning.

Table 2: Results of the GAMLSS models (Weibull distribution)

	Model I (periods 1-10)			Model II (periods 6-10 only)		
	Estimate	Exp (estimate)	p- value	Estimate	Exp (estimate)	p-value
Intercept	0.967	2.631	0.000	0.977	2.655	0.000
Dummy control ^a	0.011	1.011	0.545	-	-	-
Dummy pesticide tax	-0.111	0.895	0.000	-0.071	0.931	0.000
Dummy green nudge	-0.043	0.958	0.023	-0.073	0.929	0.000
Dummy favourable weather	-0.089	0.915	0.000	-0.070	0.933	0.000
Age	0.004	1.004	0.023	0.006	1.006	0.015
Agricultural training	0.000	1.000	0.978	-0.011	0.989	0.344
Family farm	0.015	1.015	0.097	0.044	1.045	0.000
Gender (female)	-0.089	0.915	0.000	-0.127	0.880	0.000
Period	-0.007	0.993	0.013	-0.020	0.980	0.000
Product price winter wheat	0.015	1.016	0.017	0.017	1.017	0.015
Risk self-assessment	-0.005	0.995	0.056	-0.003	0.997	0.424
No. of observations	1,100			550		
Global deviance	1,543			642		
AIC	1,764			858		

^a Periods 6-10 coded as reference.

Source: Own calculations.

Both models reflect the relationship between the weather conditions and the applied pesticides in the business management game. The dummy variable for favourable weather conditions separates changes in TFI related to environmental conditions in the business management game from those induced by the policy treatments. If environmental conditions are favourable, the TFI significantly declines by 8.5 % (model I) or 6.7 % (model II). In contrast, the TFI rises by 1.6 % (model I) or 1.7 % (model II) for an increase in the winter wheat price by 1 €/dt. The covariate ‘period’ captures the downward trend of the TFI (Figure 3). With every period, the TFI declines by 0.7 % (model I) or 2.0 % (model II).

4. Conclusion

Besides the debate about the introduction of pesticide taxes to reduce negative externalities from intensive chemical crop protection, there is emerging research on green nudges to foster environmental friendly behaviour. Nevertheless, there is no empirical evidence how farmers

might respond to these two policies at farm-level. With this in mind, the main goal of our study was to experimentally investigate the effects of a pesticide tax and a green nudge (in form of traffic light labelling of pesticide intensities) on pesticide applications. We conducted an incentivised business management game in which a sample of German agricultural students managed a ‘virtual’ cash-crop farm and had to choose their cropping, tillage and pesticide strategies during several production periods while facing uncertain price and weather conditions.

The pesticide tax and green nudge are designed in a way to reduce pesticide intensities approximated by the chosen TFI in the business management game. We evaluate both policies in terms of their effectiveness, economic consequences at farm level and possible adjustments of crop rotation and tillage practices (Oskam et al., 1997). A within-subject comparison reveals that the implementation of both policy measures reduced the TFI. According to our regression model, the TFI in the pesticide tax treatment and green nudge treatment declines by 10.5 % and 4.2 %, respectively. The economic consequences of both policies are assessed by the change in profits compared to the control group (between-subject comparison of means). On average, the introduction of the pesticide tax and green nudge results in a decline in profits by 79 €/ha and 10 €/ha, respectively. Furthermore, the analysis of the crop and tillage decisions reveals that participants with pesticide tax treatment tend to cultivate less winter wheat in favour of silage maize, which requires fewer pesticide treatments. In addition, the implementation of the pesticide tax leads to a shift from conservation to conventional tillage strategies involving a lower TFI. We do not find such adjustment effects in the green nudge group.

The pesticide tax increases the costs for pesticide applications, and thus, provides an economic incentive to adjust pesticide intensities. In contrast, nudging intends to influence the behaviour by altering the decision environment without economic incentives (Thaler and Sunstein, 2008). Traffic light labelling of pesticide strategies sends a signal to participants that high pesticide intensities coloured in red are less desirable from society’s perspective.

A further important implication from our results for the pesticide tax is that farmers’ agronomic adjustments to reduce the tax burden could involve unintended ecological effects. For instance, conventional tillage exhibits a higher energy demand and is likely to increase the exposure of soil erosion (Montgomery, 2007). Additionally, cultivation of crops with low pesticide demands might increase and result in crop rotations with only a few crops. For example, the expansion of maize production is particularly criticised by the public in Germany (Linhart and Dhungel, 2013). These findings enhance understanding of pesticide policies and could be useful for policy makers.

The external validity of experimental approaches, as applied in this study, is limited to some extent (Roe and Just, 2009). We mitigate this drawback by means of a realistic framing of the decision situation. Nevertheless, we admit that economic reality is more complex than portrayed in the business simulation game. For instance, farmers can choose between a variety of pesticide products with different toxicity levels. Future experimental research should address the analysis of more differentiated pesticide taxes as advocated in the literature (Böcker and Finger, 2016). Although, winter wheat and silage maize account for 45 % of the arable land in Germany (Statistisches Bundesamt, 2018), farmers may also opt for other crops. Likewise, additional mechanical weed control using harrows or cultivators is likely to gain in importance and should be considered in future research. Actual implementation costs of the pesticide tax and green nudge are beyond the scope of our study, but are relevant from a welfare perspective. Moreover, one might be tempted that the subject pool of students in our study may exacerbate generalisations about the response behaviour of farmers. However, this might not be the case for two reasons. Firstly, we use students of agricultural sciences of which 40.0 % completed an agricultural training and 65.5 % grew up on farm, and are familiar with agricultural production decisions. Secondly, other studies have shown that students and farmers can respond in similar ways to policy measures (cf., e.g., Peth and Mußhoff 2018). Notwithstanding these limitations, business management games are a useful tool for ex ante

policy impact analysis that can contribute to more efficient design of policies at the farm level. This holds particularly true for ‘smart’ policies that do not involve economic incentives, such as green nudges.

Literatur

- Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics* 95(9), 1082–1095.
- Andersen, M.S. and Sprenger, R.-U. (2000). *Market-based instruments for environmental management: Politics and institutions*. Edward Elgar Publishing, Cheltenham.
- Andert, S., Bürger, J. and Gerowitt, B. (2015). On-farm pesticide use in four Northern German regions as influenced by farm and production conditions. *Crop Protection* 75, 1–10.
- Arno, A. and Thomas, S. (2016). The efficacy of nudge theory strategies in influencing adult dietary behaviour: a systematic review and meta-analysis. *BMC Public Health* 16, 676.
- Barnes, A.P., Toma, L., Willock, J. and Hall, C. (2013). Comparing a ‘budge’ to a ‘nudge’: Farmer responses to voluntary and compulsory compliance in a water quality management regime. *Journal of Rural Studies* 32, 448–459.
- Benartzi, S., Beshears, J., Milkman, K.L., Sunstein, C.R., Thaler, R.H., Shankar, M., Tucker-Ray, W., Congdon, W.J. and Galing, S. (2017). Should governments invest more in nudging? *Psychological Science* 28(8), 1041–1055.
- Benz, M. (2009). Entrepreneurship as a non-profit-seeking activity. *International Entrepreneurship and Management Journal* 5(1), 23–44.
- Bobek, D.D., Roberts, R.W. and Sweeney, J.T. (2007). The social norms of tax compliance: Evidence from Australia, Singapore, and the United States. *Journal of Business Ethics* 74(1), 49–64.
- Böcker, T. and Finger, R. (2016). European pesticide tax schemes in comparison: An analysis of experiences and developments. *Sustainability* 8(4), 378.
- Bocquého, G., Jacquet, F. and Reynaud, A. (2014). Expected utility or prospect theory maximisers? Assessing farmers’ risk behaviour from field-experiment data. *European Review of Agricultural Economics* 41(1), 135–172.
- Buchholz, M., Holst, G. and Mußhoff, O. (2016). Irrigation water policy analysis using a business simulation game. *Water Resources Research* 52(10), 7980–7998.
- Burtless, G. (1995). The case for randomized field trials in economic and policy research. *The Journal of Economic Perspectives* 9(2), 63–84.
- Carlsson, F., Gravert, C., Johansson-Stenman, O. and Kurz, V. (2018). Green Nudging as a Policy Instrument. 6th World Congress of Environmental and Resource Economists 25-29 June 2018, Gothenburg, Sweden.
- Charness, G., Gneezy, U. and Kuhn, M.A. (2013). Experimental methods: Extra-laboratory experiments-extending the reach of experimental economics. *Journal of Economic Behavior & Organization* 91, 93–100.
- Chabé-Ferret, S., Le Coent, P., Reynaud, A., Subervie, J. and Lepercq, D. (2018). Can we nudge farmers into saving water? Evidence from a randomized experiment. CEE-M Working Paper 2018-10.
- Cooper, J. and Dobson, H. (2007). The benefits of pesticides to mankind and the environment. *Crop Protection* 26(9), 1337–1348.
- Czap, N.V., Czap, H.J., Lynne, G.D. and Burbach, M.E. (2015). Walk in my shoes: Nudging for empathy conservation. *Ecological Economics* 118, 147–158.
- Dachbrodt-Saaydeh, S., Sellmann, J., Strassmeyer, J., Schwarz, J., Klocke, B., Krengel, S. and Kehlenbeck, H. (2018). *Netz Vergleichsbetriebe Pflanzenschutz–Zwei-Jahresbericht 2015 und 2016. Analyse der Ergebnisse der Jahre 2007 bis 2016. Berichte aus dem Julius Kühn-Institut*.
- Dixit, A.K. and Pindyck, R.S. (1994). *Investment under uncertainty*. Princeton University Press, Princeton, New Jersey.
- Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J. and Wagner, G.G. (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association* 9(3), 522–550.
- Dörschner, T. and Mußhoff, O. (2015). How do incentive-based environmental policies affect environment protection initiatives of farmers? An experimental economic analysis using the example of species richness. *Ecological Economics* 114, 90–103.
- Egebark, J. and Ekström, M. (2016). Can indifference make the world greener? *Journal of Environmental Economics and Management* 76, 1–13.
- Elliot, A.J., Maier, M.A., Moller, A.C., Friedman, R. and Meinhardt, J. (2007). Color and psychological functioning: The effect of red on performance attainment. *Journal of experimental psychology: General* 136(1), 154.
- Finger, R., Möhring, N., Dalhaus, T. and Böcker, T. (2017). Revisiting pesticide taxation schemes. *Ecological Economics* 134, 263–266.
- Galle, B. (2014). Tax, Command or Nudge: Evaluating the New Regulation. *Texas Law Review* 92.
- Goldin, J. and Lawson, N. (2016). Defaults, mandates, and taxes: Policy design with active and passive decision-makers. *American Law and Economics Review* 18(2), 438–462.
- Gsottbauer, E. and van den Bergh, J.C. (2011). Environmental policy theory given bounded rationality and other-regarding preferences. *Environmental and Resource Economics* 49(2), 263–304.
- Guala, F. (2005). *The methodology of experimental economics*. Cambridge University Press, Cambridge.
- Hammond, D., Fong, G.T., McNeill, A., Borland, R. and Cummings, K.M. (2006). Effectiveness of cigarette warning labels in informing smokers about the risks of smoking: Findings from the International Tobacco Control (ITC) Four Country Survey. *Tobacco control* 15(suppl 3), iii19–iii25.
- Hermann, D., Sauthoff, S. and Mußhoff, O. (2017). Ex-ante evaluation of policy measures to enhance carbon sequestration in agricultural soils. *Ecological Economics* 140, 241–250.
- Holst, G., Mußhoff, O. and Dörschner, T. (2014). Policy impact analysis of penalty and reward scenarios to promote flowering cover crops using a business simulation game. *Biomass and Bioenergy* 70, 196–206.
- Jahn, M., Wagner, C., Moll, E. and Pallutt, B. (2010). Auftreten und Bekämpfung von Krankheiten in Wintergetreide in einem Dauerfeldversuch auf dem Versuchsfeld Dahnsdorf. *Journal für Kulturpflanzen* 62(10), 248–258.

-
- Kahneman, D. (2011). *Thinking, Fast and Slow*. Penguin Books, London.
- Kahneman, D., Knetsch, J.L. and Thaler, R.H. (1991). Anomalies: The endowment effect, loss aversion, and status quo bias. *Journal of Economic perspectives* 5(1), 193–206.
- Keys, B. and Wolfe, J. (1990). The role of management games and simulations in education and research. *Journal of management* 16(2), 307–336.
- KTBL (2018). Leistungs-Kostenrechnung Pflanzenbau. <https://daten.ktbl.de/dslkrpflanze/postHv.html> (Accessed 14 February 2018).
- Kuhfuss, L., Préget, R., Thoyer, S. and Hanley, N. (2015). Nudging farmers to enrol land into agri-environmental schemes: The role of a collective bonus. *European Review of Agricultural Economics* 43(4), 609–636.
- LfL (several years). Langzeitversuch zur Reduktion des Pflanzenschutzmitteleinsatzes: Versuchsergebnisse aus Bayern - Unkrautbekämpfung in Ackerbau und Gemüsebau 2006 - 2016. Bayerische Landesanstalt für Landwirtschaft, Institut für Pflanzenschutz, Freising.
- Linhardt, E. and Dhungel, A.-K. (2013). Das Thema Vermaisung im öffentlichen Diskurs. *Berichte über Landwirtschaft - Zeitschrift für Agrarpolitik und Landwirtschaft* 91(2).
- Maybery, D., Crase, L. and Gullifer, C. (2005). Categorising farming values as economic, conservation and lifestyle. *Journal of Economic Psychology* 26(1), 59–72.
- Möckel, S., Gawel, E., Bretschneider, W., Kästner, M., Liess, M. and Knillmann, S. (2015). Eine Abgabe auf Pflanzenschutzmittel für Deutschland. *Natur und Recht* 37(10), 669–677.
- Montgomery, D.R. (2007). Soil erosion and agricultural sustainability. *Proceedings of the National Academy of Sciences* 104(33), 13268–13272.
- Mußhoff, O. and Hirschauer, N. (2014). Using business simulation games in regulatory impact analysis—the case of policies aimed at reducing nitrogen leaching. *Applied Economics* 46(25), 3049–3060.
- Oerke, E.-C. (2006). Crop losses to pests. *The Journal of Agricultural Science* 144(1), 31–43.
- Olstad, D.L., Vermeer, J., McCargar, L.J., Prowse, R.J.L. and Raine, K.D. (2015). Using traffic light labels to improve food selection in recreation and sport facility eating environments. *Appetite* 91, 329–335.
- Oskam, A.J., Vijftigschild, R.A.N., Graveland, C. and van Dam, Y.K. (1997). Additional EU policy instruments for plant protection products: Possibilities for future EC environmental policy on plant protection products. Final Report. Wageningen Agricultural University, Wageningen.
- Pallutt, B., Jahn, M., Freier, B. and Moll, E. (2010). Dauerfeldversuche auf dem Versuchsfeld Dahnsdorf unter besonderer Berücksichtigung der Unkrautbekämpfung. *Journal für Kulturpflanzen* 62(7), 238–247.
- Pedersen, A.B. and Nielsen, H.Ø. (2017). Effectiveness of pesticide policies: Experiences from Danish pesticide regulation 1986-2015. In: Coll, M. and Wajnberg, E. (eds) *Environmental pest management: Challenges for agronomists, ecologists, economists and policymakers*, pp. 297–324. John Wiley and Sons Ltd, Hoboken, NJ.
- Pedersen, A.B., Nielsen, H.Ø. and Andersen, M.S. (2015). The Danish pesticide tax. In: Lago, M., Mysiak, J., Gómez, C.M., Delacámara, G. and Maziotis, A. (eds) *Use of economic instruments in water policy: Insights from international experience*, pp. 73–87. Springer, Cham.
- Peth, D. and Mußhoff, O. (2018). Comparing compliance behaviour of students and farmers: Implications for agricultural policy impact analysis. Discussion Paper No. 1809, Georg-August-Universität Göttingen, Department of Agricultural Economics and Rural Development, Göttingen.
- Peth, D., Mußhoff, O., Funke, K. and Hirschauer, N. (2018). Nudging farmers to comply with water protection rules: Experimental evidence from Germany. *Ecological Economics* 152, 310–321.
- Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A. and D'Amore, M. (1992). Environmental and economic costs of pesticide use. *BioScience* 42(10), 750–760.
- Rigby, R.A. and Stasinopoulos, D.M. (2005). Generalized additive models for location, scale and shape. *Journal of the Royal Statistical Society: Series C (Applied Statistics)* 54(3), 507–554.
- Roe, B.E. and Just, D.R. (2009). Internal and external validity in economics research: Tradeoffs between experiments, field experiments, natural experiments, and field data. *American Journal of Agricultural Economics* 91(5), 1266–1271.
- Samuelson, W. and Zeckhauser, R. (1988). Status quo bias in decision making. *Journal of Risk and Uncertainty* 1(1), 7–59.
- SCB (2017). Plant protection products in Swedish agriculture 2017. Statistics Sweden. https://www.scb.se/contentassets/591d98d6c9454fe483a3f8435ffa8b5d/mi0501_2017a01_sm_mi31sm1801.pdf (Accessed 28 August 2018).
- Schubert, C. (2017). Green Nudges: Do they work? Are they ethical? *Ecological Economics* 132, 329–342.
- Sexton, S.E., Lei, Z. and Zilberman, D. (2007). The economics of pesticides and pest control. *International Review of Environmental and Resource Economics* 1(3), 271–326.
- Simon, H.A. (1990). Invariants of human behavior. *Annual Review of Psychology* 41(1), 1–20.
- Skevas, T., Stefanou, S.E. and Lansink, A.O. (2012). Can economic incentives encourage actual reductions in pesticide use and environmental spillovers? *Agricultural Economics* 43(3), 267–276.
- Statistisches Bundesamt (2018). Land- und Forstwirtschaft, Fischerei Bodennutzung der Betriebe (Struktur der Bodennutzung) Fachserie 3 Reihe 2.1.2.
- Sunstein, C.R. (2014). Nudging: a very short guide. *Journal of Consumer Policy* 37(4), 583–588.
- Sunstein, C.R. and Reisch, L.A. (2014). Automatically green: Behavioral economics and environmental protection. *Harvard Environmental Law Review* 38, 127.
- Thaler, R.H. and Sunstein, C.R. (2008). *Nudge: Improving decisions about health, wealth and happiness*. Penguin, London.
- Tversky, A. and Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty* 5(4), 297–323.
- Vries, F.P. de and Hanley, N. (2016). Incentive-Based Policy Design for Pollution Control and Biodiversity Conservation: A Review. *Environmental and Resource Economics* 63(4), 687–702.