HOW DO AGRICULTURAL TRADE POLICIES AFFECT THE REGIONAL ENVIRONMENT? AN INTEGRATED ANALYSIS FOR THE AUSTRIAN MARCHFELD REGION

MATHIAS KIRCHNER AND ERWIN SCHMID

Abstract

It remains difficult to derive general findings and conclusions from either economic theory or empirical studies on the relationship between trade and environment. Consequently, the aim of this paper is to analyse environmental effects of agricultural trade policies in the Austrian Marchfeld region by applying an integrated modelling framework that accounts for heterogeneity in agricultural production and emission. Monte-Carlo simulations have been performed in order to assess the uncertainty of model parameters and policy impacts. The model results indicate that changes in trade policies have only small effects on the environment in Marchfeld. Hence, policy makers should concentrate on identifying efficient domestic environmental policies that are in accordance with WTO trade rules.

Keywords

agricultural trade policies, agri-environmental payments, integrated assessment modelling, Monte-Carlo simulations, nitrate pollution, soil organic carbon

1 Introduction

According to economic theory, trade may have ambiguous effects on welfare if production and/or consumption of a traded good generates positive or negative externalities (Anderson, 1992; Krutilla, 2002), especially if classical assumptions such as well-defined property rights or zero transactions costs are relaxed (Chichilnisky, 1994; Vatn, 2002; Norgaard and Jin, 2008). At the regional level, liberalizing or distorting trade of agricultural commodities may lead to substantial changes in input and output prices and may thus be able to significantly alter farmers' land use and management choices (Barbier, 2000). Any changes in these production choices may consequently change the generation of externalities.

Many empirical studies on agricultural trade and environment linkages have been conducted at a global or European level (Maltais et al., 2002; Morrissey et al., 2005; Sullivan and Ingram, 2005; Saunders et al., 2006; van Meijl et al., 2006; Verburg et al., 2009; Hermans et al., 2010; Schmitz et al., 2012) and at a national level (Beghin, 1997; Barbier, 2000; Williams and Shumway, 2000; Cooper, Johansson, et al., 2005; Würtenberger et al., 2006; Sinabell, 2009; Gumilang et al., 2011), yet only few at a more regional level (López, 1997; Fraser, 2006; Henseler et al., 2009; Briner et al., 2012). Despite the numerous studies on trade and environment, Zilberman (2011, p. 29) claims that 'economists have not paid much attention to the environmental implications of trade'. Overall they studies cited above show mixed results with regard to the environmental effects of trade policies, although non-OECD countries are rather likely to experience negative environmental effects (especially deforestation due to land expansion). One central theme in the trade and environment research is that that the effects of agricultural trade policy changes on the environment will differ largely between regions and pollutants, and that the dynamic and heterogenous effects of production (e.g. land use choices) should be considered in such analyses. Although regional assessments may omit important linkages that would be captured by national and global analyses (e.g. changes in world prices due to a new trade liberalization agreement), they are much better suited for the assessment of environmental effects (Ervin, 2000; Maltais et al., 2002). So far, regional empirical studies are very limit in numbers and in their scope. This in turn means that more research, especially regional case studies, are needed in order to investigate how to response adequately (Antle et al., 1998; Barbier and Bulte, 2004; Cooper, Bernstein, et al., 2005; Henseler et al., 2009; Hermans et al., 2010).

The aim of this paper is to conduct a regional case study analysis in the Austrian Marchfeld region in order to analyse how changes in agricultural tariffs and agri-environmental schemes may affect nitrogen leaching and soil organic carbon (SOC) content in ploughing depth (≤30cm). Consequently, a regional land use optimization model has been developed, which integrates outputs from the biophysical simulation model EPIC (Environmental Policy Integrated Climate) to account for the heterogeneity in agricultural production and emission. Monte-Carlo simulations have been performed in order to account for the uncertainties of model parameters, such as annual variations in crop prices and, due to the yet undecided reform path of the Common Agricultural Policy (CAP) after 2013 (European Commission, 2011), also for tariffs and agri-environmental payments.

2 Data

Marchfeld – an important crop production region – is located in the Vienna Basin in the very East of Austria. The total area amounts to about 1,000 km² most of which is mainly arable lands (~700 km²). Crops that are predominantly produced in the region are cereals, root crops, and vegetables. The regional climate is characterized as semi-arid with annual precipitation sums of around 550 mm (Thaler et al., 2012). Nitrate pollution of groundwater has become a serious problem in the region, most likely due to the expansion of intensive agriculture from the 1970s onwards. Data on groundwater quality shows that average nitrate concentrations in Marchfeld are constantly above the legal threshold level for groundwater (45 mg/l) (Umweltbundesamt, 2006, 2011). In addition, maintaining a soil productivity, and thus – inter alia – SOC content, will become more important in Marchfeld in the near future in order to become more resilient to likely climatic changes such as warmer temperatures, drier summers and possibly an increase in heavy rainfalls (Klik and Eitzinger, 2010; Trnka et al., 2011; Strauss et al., 2012; Thaler et al., 2012).

The Marchfeld region is divided into five sub-regions with similar land use characteristics. Due to the complex geological genesis of the Vienna Basin, more than 300 different soil types have been mapped in this region, e.g. chernozems, cambisols, gley, and brash. These soils have been clustered according to humus content in top soil and available soil water capacity, which has resulted in five soil clusters of which five typical soils have been selected from Hofreither et al. (2000). Relative crop shares for carrots, onions, sugar beet, field peas, green peas, spinach, potatoes, early potatoes, fallow land, winter barley, summer barley, corn, durum wheat, winter wheat, winter rye, sunflower, and winter rapeseed have been used in the CropRota model (Schönhart et al., 2011) to derive 13 typical crop rotation systems.

Environmental data is obtained from the biophysical process model EPIC (Williams, 1995; Izaurralde et al., 2006). Many processes are modelled at daily time step and smaller. The outcomes primarily depend on land use, elevation, slope, soil types, agronomic measures, and climate data. Outputs refer to the edge of a field and are provided for – inter alia – dry matter crop yield, straw yield, percolation, evapotranspiration, SOC content in ploughing depth (≤30cm), and nitrogen leaching. Agronomic measures simulated for this case study include tillage measures (conventional, reduced and minimum), crop management measures (fertilizer management and cover cropping), and straw management measures (w/o straw harvest). While most of these agronomic measures can be combined, we do not allow in the model to apply cover crops (and thus also a combination of fertilizer splitting and cover crops = 'combined environmental measure') together with conservation tillage (reduced or minimum).

Annual crop prices from 1998 to 2010 have been taken into account in the analysis (Statistics Austria, 2012). Average most-favourite nation applied tariffs for 1998 and 2010 are obtained from the 'Tariff Analysis Online' database (WTO, 2012). Payments for agri-environmental measures are taken from 'The Austrian Programme for Rural Development 2007-2013' (BMLFUW, 2009). Payments for environmentally friendly management measure in the model consist of (1) fertilizer splitting and reduced nitrogen fertilizer application, (2) cover crop systems and (3) a combination of both. Farmers also receive agri-environmental payments for applying soil conserving measures, such as mulching and direct seeding (i.e. equivalents to reduced and minimum tillage, respectively). Historical crop payments have also been included (i.e. coupled crop payments) in order to analyse the effects of protective measures. We also included the current payment scheme, which derived from the latter, i.e. single farm payments (these payments are de-coupled from production, i.e. farmers do not have to grow specific crops to be eligible)[1]. Variable production costs per hectare have been computed using the standard gross margin catalogue (BMLFUW, 2008) and own data sources.

In our analysis, we assume that agri-environmental payments can be provided independently for environmentally friendly management and conservation tillage measures in order to account for their individual effects. Therefore, we distinguish between payments for environmentally friendly management practices (i.e. environmental management payments) and for conservation tillage practices (i.e. conservation tillage payments). The term agri-environmental measures/payments will always refer to both.

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[1] For more information on economic data see Table 5 to Table 7 in the appendix.

3 Method

The methodological framework for the case study is depicted in Figure 1. It shows how both economic and environmental data are integrated in a linear regional land use optimization model and how model parameter uncertainty is assessed.

Our framework follows the footsteps of Antle and Capalbo (1998), who have developed a static spatial model for assessing economic and environmental trade-offs in agricultural production. The basic idea behind their modeling approach is that environmental impacts cannot be assessed accurately at an aggregate level. Therefore, a more disaggregated economic analysis is needed on a field specific level which fits better to a typical soil science analysis. The framework shows that it is essential to know the drivers of land use and management choices. The characteristics of land and technology as well as the prices for inputs and outputs influence farmers' land use and management choices (i.e. crops, tillage, straw and agri-environmental measures). These production choices together with the ecological characteristics of the land will then determine crop yields and the location-specific environmental outcomes (which is all accounted for in the EPIC simulations).

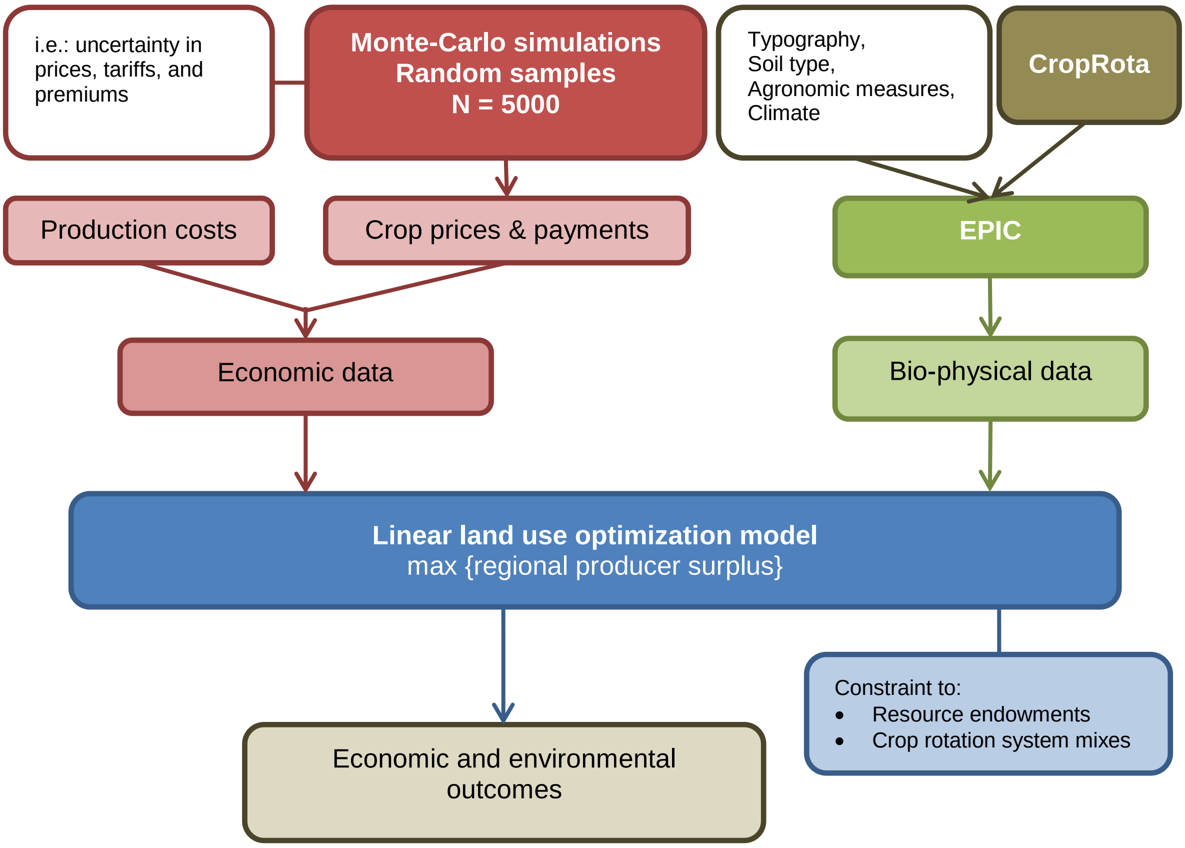

Figure 1: The integrated modelling framework
Source: own

On the one hand, the model is fed with economic data, such as production costs, crop prices, tariffs and payments. Monte Carlo simulations are used to reflect the uncertainty in crop prices, tariffs, and payments. On the other hand, biophysical data from EPIC provide important information on the level and heterogeneity of crop yields – which are further used in the computation of gross margins – as well as on the environmental effects (e.g. nitrogen leaching, percolation, SOC content) of alternative crop production choices. Input of relative crop rotation shares to EPIC is provided by the CropRota model (Schönhart et al., 2011). The objective of the land use optimization model is to obtain a production portfolio that maximizes average annual regional producer surplus (our bio-physical simulations account for the dynamics of 12 years) subject to resource endowments and crop rotational constraints. The model can be described with the following set of equations:

$$\max \quad f(d,X) = \sum_p (d_p X_p) \quad (1)$$

$$s.t. \quad \sum_p (A_{p,j} X_p) \leq b_j \quad \forall j \quad (2)$$

$$\sum_m (\theta_m M_{m,p}) \leq X_p \quad \forall p \quad (3.1)$$

$$\sum_p (X_p) \leq \sum_m \left(\theta_m \sum_p (M_{m,p}) \right) \quad (3.2)$$

$$X_p \geq 0 \quad (4)$$

The objective function (1) maximizes average regional producer surplus (*RPS*). Therefore, it is defined as the sum of the product of crop production choices (*X*) and the gross margins (*d*). The index *p* represents crop production choices, i.e. sub-regions, soil types, crop rotation systems, tillage systems, straw management, and crop management measures. The model is constrained by arable land (*b*) available in sub-region and soil type, indexed by *j* (2). *A* is the Leontief technology matrix to convert resources into crop products. In order to avoid overspecialisation in a linear programming model, we use a convex set of alternative crop rotation systems based on 13 alternative mixes of crop rotation system shares, which have been derived from the CropRota model (3.1 and 3.2, where *θ* is the choice variable for the crop rotation mix and *M* the parameter for available mixes, indexed by *m*). The model has been programmed with the General Algebraic Modelling System (GAMS[2]) and solved with the CPLEX solver.

Monte-Carlo simulations have been performed to assess uncertainties of important parameters. This type of sample-based uncertainty and sensitivity analysis allows displaying and assessing the impact of uncertainties in crop prices, tariffs, and policy payments on environmental model outcomes (Helton and Davis, 2000). Distributions for prices, tariffs and payments have been assumed based on data and other information (see Table 1).

Table 1: Type of distributions for main parameters

Parameters		Type of distribution	Sources
Crop prices		truncated normal distributions with $\mu = (up_{limit} + lo_{limit}) / 2$ and $\sigma = (\mu - up_{limit}) / 1.96$	Statistics Austria (2012) Salhofer et al. (2006) Schmidt et al. (2010)
Tariffs		uniform distributions	WTO (2012)
Agri-environmental payments	Management	Bernoulli distribution (dummy) With *p = 0.5*	BMLFUW (2009)
	Conservation tillage		
Support payments	Coupled crop payments		BMLFUW (2002)
	Single farm payments		AMA (2012), LK NÖ (2012)

Exactly 5000 independent random samples have been drawn from these distributions and implemented in the optimization model. These 5000 model results are further analysed by applying linear multiple regression analyses (5) in order to assess the relative influence of model parameters on nitrogen leaching and SOC content:

$$Y_E = \beta_0 + \sum_{c=1}^{n} (\beta_{p,c} p_c) + \sum_{c=1}^{n} (\beta_{t,c} t_c) + \sum_{k=1}^{n} (\beta_k prem_k) + e \quad (5)$$

[2] see www.gams.com [accessed 2012-01-12]

Environmental outputs *Y* (where the index *E* comprises of nitrate concentrations and SOC) are thus linearly dependent on crop prices *p* and crop tariffs *t*, where the index *c* represents crops, and also on policy payments *prem*. Five possible policy variables are represented by the index *k* and include: (1) environmental management payments; (2) conservation tillage; (3) the combined payment effect of providing both agri-environmental payments, (4) coupled crop payments and (5) single farm payments. These payments enter the regression model as dummy variables. Standard linear model assumptions require, inter alia, that the sampling distribution is normal in order to exactly infer t and F distributions. This is usually not the case in sampling-based sensitivity studies (Helton and Davis, 2000). However, the large number of observations ($n = 5000$) allows to apply an OLS estimator even if the dependent variable is not close to being normally distributed. The central limit theorem shows that, given a large sample and other standard assumptions, "OLS standard errors, t statistics and F statistics are asymptotically valid" (Wooldridge, 2002, p. 60).

4 Results

Before we begin to present the results of our integrated model analysis we first give some insight into our EPIC simulations. This should provide information on the environmental effects of the different production choices and helps to better understand and interpret the results of our integrated analysis.

4.1 The environmental effects of land use and management

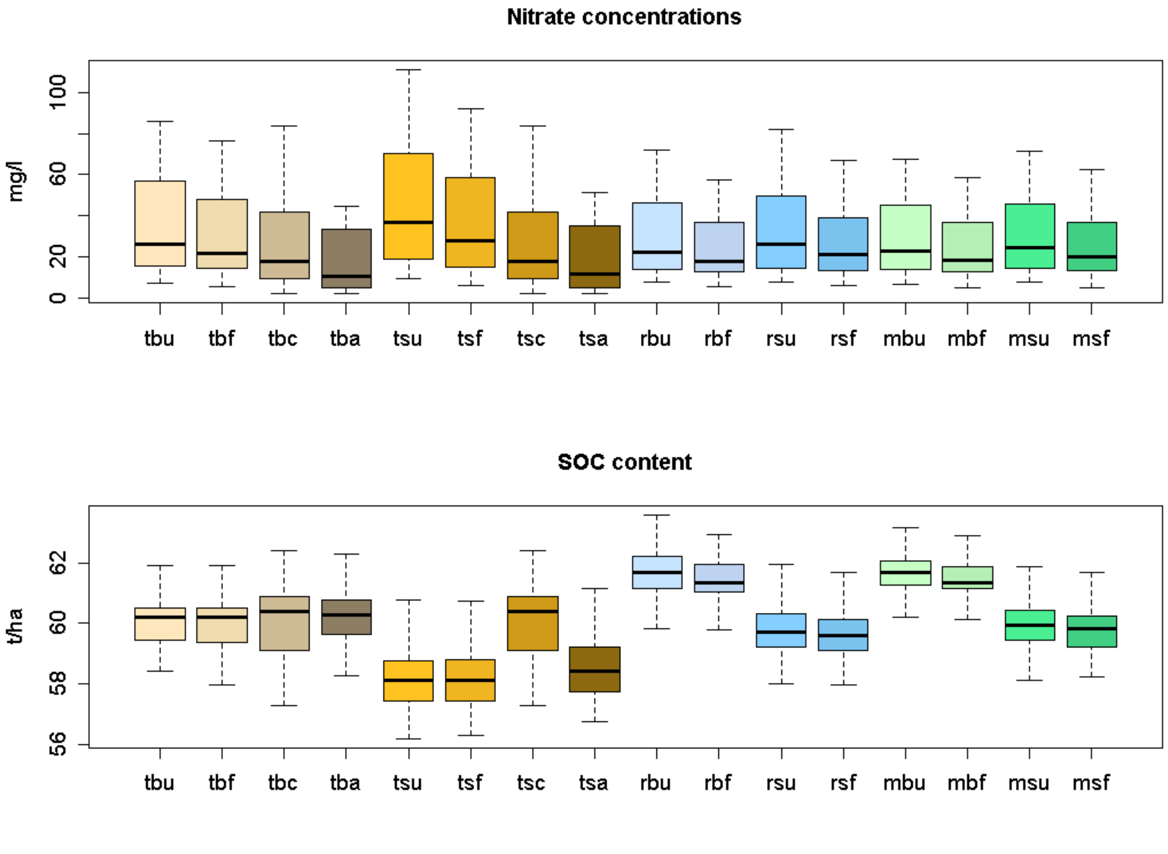

Figure 2: Variations for nitrate concentrations and SOC content on soil type 1

First letter (tillage): t … conventional tillage; r … reduced tillage; m … minimum tillage

Second letter (straw): b … no straw harvest (base); s…straw harvest

Third letter (crop): u … usual fertilizer regime; f … fertilizer splitting; c … cover crops; a … f & c

Source: own calculations

Figure 2 depicts the variations in nitrogen leaching (i.e. nitrate concentrations of percolation water below 1.2 m) and SOC content in ploughing depth (≤30 cm) for all possible agronomic management options (i.e. tillage systems, straw management and crop management measures) on soil type 1 (which is most abundant in Marchfeld)[3] according to our EPIC simulations. Variations are caused, inter alia, due to different crop rotation systems and weather.

Nitrate concentration levels in percolation water seem to be significantly lower if environmentally friendly measures are applied. A combined environmental measure (*a*) shows lower nitrate concentration levels than cover crops (*c*) followed by fertilizer splitting (*f*). In addition, reduced (*r*) and minimum (*m*) tillage seem to perform better than conventional tillage (c.p.). However, a combination of conventional tillage (*t*) and the combined environmental measure seems to yield the lowest nitrate concentrations (independently of straw management). This combination also provides the lowest maximum outliers. Straw harvest (*s*) seems to have no effect on nitrate concentrations in percolation water.

Conservation tillage shows substantial improvements in SOC content compared to conventional tillage. In contrast, straw harvest has strong detrimental effects on SOC content, most likely due to the removal of harvest residues (Zuazo et al., 2011; Powlson et al., 2012). However, this negative effect could be completely mitigated if cover crops are sawn. The effects of fertilizer splitting are mixed with very small positive effects in the case of conventional tillage measures and slightly negative effects in the case of conservation tillage. A combined environmental measure has marginal positive effects compared to standard fertilization measures.

The EPIC simulations for conservation tillage measures, cover crops and fertilizer splitting on both nitrogen leaching and SOC content are in accordance with findings of an empirical field study in Marchfeld (Freudenschuß et al., 2010). However, fertilizer splitting shows a more pronounced positive effect on SOC content in the field study.

4.2 Analysing the environmental effects of trade policies

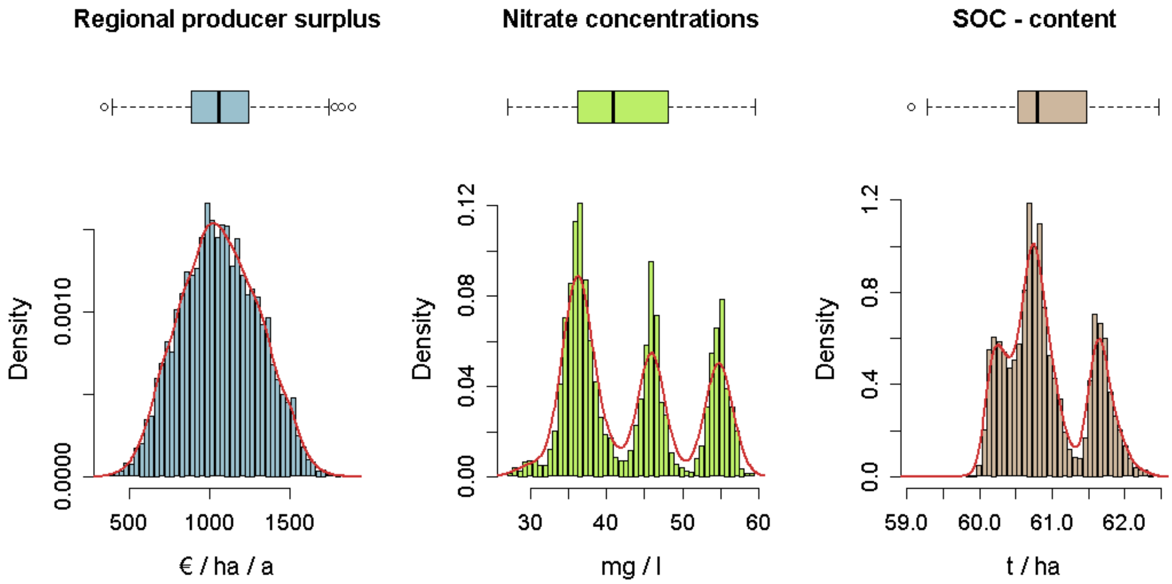

Figure 3: Distributions of model outputs
Source: own calculations

The results of our integrated model analysis are illustrated in Figure 3. The uncertainty in average annual values for regional producer surplus, nitrate concentrations and SOC content is visualised by the means of histograms, boxplots and density functions. The distribution of regional producer surplus (RPS) is normally distributed. The annual per hectare values range from €342 to €1882 with a mean of €1064 and a standard deviation of €245. Nitrate concentrations and SOC content are distributed multimodal with three distinct peaks. These peaks are a likely result of the Bernoulli distribution of environmental management and conservation tillage payments, which have substantial effects on

[3] The relative impact of land management measures on nitrate concentrations and SOC content is nearly the same on all soils (see Figure 6 in the appendix).

nitrate pollution and SOC content. Hence, descriptive statistical values, such as maximum (59.5 mg/l and 62.5 t/ha), minimum (26.9 mg/l and 59.1 t/ha), mean (43.0 mg/l and 60.9 t/ha) and standard deviation (7.9 mg/l and 0.5 t/ha) are not proper measurements for displaying such subjective uncertainty (Helton and Davis, 2000).

In order to identify the relative influences of each parameter on these model outcomes simple OLS regression analyses were conducted (see section 3). Table 2 depicts the results of these OLS regression analyses using mean values for crop prices and tariff (in order to provide a more convenient presentation)[4]. Only parameters with a significance of $\alpha = 0.01$ are included, as this is a common approach in sensitivity analyses (Helton and Davis, 2000). All models seem to sufficiently explain most of the variation, with adjusted R^2 values of 0.84, 0.94 and 0.88 for RPS, nitrate concentrations and SOC content, respectively.

Table 2: Results of the OLS regression analyses (best fit) – mean values

	Regional Producer Surplus [€/ha]		Nitrate concentrations [mg/l]		SOC content [t/ha]	
Parameter	**Estimate**		**Estimate**		**Estimate**	
Intercept	-1000.0412	***	44.794	***	61.292	***
Environmental management payments	85.6874	***	-18.775	***	-0.474	***
Conservation tillage payments	34.2218	***	-8.847	***	0.936	***
*Combined agri-environmental payments (environmental * conservation tillage)*	-26.8167	***	9.523	***	-0.374	***
Coupled crop payments	248.9224	***	-0.450	***	0.014	***
Single farm payments	304.3444	***				
Mean crop prices[1]	9.3084	***	0.052	***	-0.003	***
Mean crop tariffs	14.2656	***	0.091	***	-0.005	**
Ad. R^2	*0.84*		*0.94*		*0.88*	
N	*5000*		*5000*		*5000*	

Level of significance: *** … p<0.001; ** … p<0.01
Source: own calculations

All parameters seem to have significant and mostly positive effects on average annual **RPS**. This is of course not surprising, as increases in (mean) prices and (mean) tariffs as well as payments should consequently increase farmers' revenues (c.p.). The contribution of coupled and single farm payments to RPS is much larger than those of agri-environmental payments. Nevertheless, the latter still make up a substantial part of RPS and may thus give an important incentive for farmers to increase their share of agri-environmental measures in the production portfolio. However, the negative and statistically significant coefficient for combined agri-environmental payments (i.e. the *'combined payment effect'* for providing environmental management and conservation tillage payments at the same time) shows that one cannot simply sum up their individual contributions when provided at the same time. Hence, the increase in RPS when both agri-environmental payments are made is not just the sum of each of them (119.9 €/ha) but also needs to include the 'combined payment effect'. Since this effect is negative the net result shows that RPS will increase by 93.1 €/ha if both payments are made at the same time which is still more than their single individual contributions (85.7 €/ha or 34.2 €/ha). This indicates that, if a combined payment is introduced, not all farmers will apply measures that are eligible for both payments (i.e. conservation tillage and fertilizer splitting; see Table 3 for an overview). For some it may be more profitable to apply only environmental measures (with conventional tillage) or only conservation tillage (with the usual fertilizer regime).

The regression model for average annual **nitrate concentrations** shows that all parameters, except the single farm payment, are statistically significantly influencing factors. Mean crop prices and tariffs are likely to increase nitrate concentrations. It seems that although the magnitude of impact is small (e.g. a unit increase in mean crop tariffs (one percentage point) increases nitrate concentrations by

[4] Table 8 in the appendix provides further information on regression analyses that account for the influence of individual crop prices and tariffs and the model outcomes. These more explicit regression analyses can explain a wider range of variation in all models and, of course, explain more the impact of individual crop prices and tariffs. However, the results for all other policy payments are almost identical to Table 2.

0.09 mg/l), the price changes induced by trade policy changes may still have substantial effects on nitrate concentrations. Interestingly, coupled crop payments seem to have a negative yet very marginal effect on nitrate concentrations. If included they decrease nitrate concentrations by around 0.45 mg/l. This seems surprising, especially since Sinabell (2009) found that producer support policies may contribute to increased nitrate pollution in Austria. However, Sinabell's results refer to the national level and impacts may of course differ in different regions in Austria. The EPIC simulations for Marchfeld indicate that crops eligible for coupled payments perform relatively better with regard to nitrate pollution compared to a mean value over all crops.

Table 3: The eligibility of tillage measures and crop management for agri-environmental payments

Combination of agronomic measures \ Payments		Environmental	Conservation Tillage	Combined
Tillage	**Crop management**			
Conventional	Usual fertilizer regime			
	Fertilizer splitting	YES		
	Cover crops	YES		
	Combined environmental measure	YES		
Conservation (reduced & minimum)	Usual fertilizer regime		YES	
	Fertilizer splitting	YES	YES	YES

Environmental management payments seem to have the single largest negative effect on nitrate concentrations. This is most likely due to the increased incentive they give for reducing fertilizer application rates and for sawing cover crops. They may reduce concentration levels by 18.8 mg/l. A negative effect on nitrate concentrations is further achieved by soil conservation payments which lead to a reduction of almost 8.8 mg/l. The combined payment effect seems to mitigate the negative effects of the single payments on nitrate concentrations. This may be surprising at a first glance, but can be easily explained due the restriction of applying cover crops and a combined environmental measure only together with conventional tillage (see Table 3 and section 4.1). Since a combined payment gives farmers also an incentive to increase their share of conservation tillage measures it will consequently reduce their incentive to apply a combined environmental measure (which is the best means of reducing nitrate concentrations). A simple correlation analysis corroborates this assumption (Table 4). While environmental management payments are almost fully correlated with a combined environmental measure (0.92), combined agri-environmental payments are much less correlated with this measure (0.24). Overall, providing both agri-environmental payments affects nitrate concentrations in almost the same way as if only environmental management payments are granted (-18.1 mg/l and -18.8 mg/l, respectively). This is because the combined payment effect (9.5 mg/l) and the effect for conservation tillage payments (-8.8 mg/l) cancel each other out. Hence, we can explain the nature of the multimodal distribution of nitrate concentrations in Figure 3: The left peak refers to a situation when either combined agri-environmental payments or only environmental management payments are made (as these are two events it also explains why it is the highest). The peak in the middle occurs if only conservation tillage payments are made and the one on the right illustrates a situation without agri-environmental payments. The remaining variation is caused due to the uncertainties in crop tariffs and prices.

Table 4: Pearson's product moment correlation coefficients – payments and management measures

Applied measures \ Payments		Environmental		Conservation tillage		Combined	
Tillage	conventional	0.71	***	-0.70	***	0.02	
	reduced	-0.22	***	0.83	***	0.30	***
	minimum	-0.81	***	0.53	***	-0.15	***
Management	standard fertilization	-1.00	***	0.02		-0.57	***
	fertilizer splitting	0.90	***	0.26	***	0.83	***
	cover crops	0.19	***	-0.05	**	0.06	***
	combined environmental measure (i.e. fertilizer splitting & cover crops)	0.92	***	-0.26	***	0.24	***

Level of significance: *** … p<0.001; ** … p<0.01
Source: own calculations

Higher mean crop prices and tariffs seem to negatively affect the environment with regard to average annual **SOC content**. However, the magnitude of impact is marginal. For example, a rise of one percentage point in tariffs would lead to a decrease of a mere 0.005 t/ha (or 5 kg/ha). In contrast, coupled crop payments show again a slightly positive effect on the environment. They could increase SOC content by 0.014 t/ha (or 14 kg/ha).

Soil conservation payments seem to be the only factor in the regression analysis that show a substantial positive effect on SOC content with a likely increase of up to 1 t/ha. A more surprising result is found for environmental management payments. They seem to lead to considerable lower SOC content (-0.5 t/ha), which is somewhat counterintuitive given the results of the EPIC simulations in preceding section (4.1). The correlation analysis (Table 4) reveals that payments for environmentally friendly measures give farmers an incentive to apply a combined environmental measure (only applicable with conventional tillage). Consequently they are negatively correlated with conservation tillage (-0.22 for reduced and -0.81 for minimum) but positively correlated with conventional tillage (0.71). Since conservation tillage measures provide much higher SOC content than conventional tillage this can explain the negative effect on SOC content in the regression analysis. Finally, a payment for both agri-environmental measures at the same time almost nullifies the positive effects of conservation tillage payments. This is due to the negative coefficients for both environmental management payments and the combined payment effect. Instead of an increase by 0.47 t/ha (only taking into account the single effects), SOC content only increases slightly by 0.09 t/ha. This situation is thus almost equivalent to a situation without agri-environmental payments. Both occurrences are represented by the middle peak in the distribution of SOC content (see Figure 3). The single impacts of environmental management and conservation tillage payments are reflected by the lower left peak and lower right peak, respectively.

A convenient way of illustrating the influence of model parameters is by providing probability distributions of their respective elasticities. The regression models are used to derive response surfaces in order to compute the range of elasticities (Salhofer et al., 2006; Schmidt et al., 2010). The elasticities for crop tariffs (and analogously for crop prices) are defined as:

$$e_{t_c}^{X} = \frac{\partial X}{\partial t_c}\frac{t_c}{X} = \beta_c \frac{t_c}{X} \quad (6)$$

where *t* refers to crop tariffs and *X* to the model outcomes. We restrict the analysis to environmental outcomes, as we are more interested in the environmental effects of trade policy changes. The elasticity refers to the percentage change in the dependent variable (e.g. nitrate concentrationa) for a 1% change in the independent variable (e.g. corn price or wheat tariff). It distinguishes for different points in the response surface. While it is easy to compute these distributions for prices and tariffs it is not a meaningful procedure with respect to the dummy variables in the regression model (i.e. the various policy payments), given the definition of elasticities above (p_i could only take on values of 0 and 1).

In order to provide a more convenient picture, we only discuss the probability distributions of the elasticities for mean crop prices and mean tariffs with respect to both nitrate concentrations (NO_3) and SOC content (depicted in Figure 4)[5]. The elasticities for nitrate concentrations are positive and much larger than those for SOC content, yet still relatively inelastic. A 1% change in mean crop prices may lead to increases in nitrate concentrations of at least 0.11% and up to 0.29%, with a mean of 0.18%. This may not seem like much, but given that world price volatility ranges between 20 and 50% (Morrissey et al., 2005), this could lead – in the worst case scenario – to increases in nitrate concentrations of 14.5%. The influence of crop tariffs should also not be underestimated. At first glance their influence looks almost negligible as a 1% change in mean crop tariffs may increase nitrate concentrations only between 0.02% and 0.11% (with a mean of 0.06%). However, a full elimination of domestic tariffs could lead to decreases in nitrate concentrations by around 4 to 5%, using average values. Notably, global trade liberalisation could mitigate this effect as this leads to higher world crop prices (although the effect will most likely be lower than the one for domestic tariff reductions). In addition, the OECD-FAO agricultural outlook (2012) predicts large price increases for most crops

[5] The range of elasticities for individual crop prices and tariffs is provided in Table 9 and Figure 5 in the appendix.

(between 12% for wheat and 30% for coarse grains). These price increases may very well overlay the effects of (both domestic and global) tariff changes on crop prices.

The effects of mean crop prices and tariffs on SOC content are much weaker (see Figure 4). On average, a 1% change in mean crop prices and tariffs leads to a decrease in SOC content of -0.006% and -0.002%, respectively. Given these very inelastic values, it seems fair to argue that crop prices and tariffs have a negligible effect on SOC content (e.g. the abolishment of all tariffs could, at best, merely increase SOC content by 0.1%). The only important single price parameter that may be of some influence is the price of straw (its elasticity ranges between -0.03 and -0.02; see Table 9 in the appendix). As a higher price for straw increases the incentive to remove harvest residuals from the field, this evidently has negative (yet in our case very small) effects on SOC content.

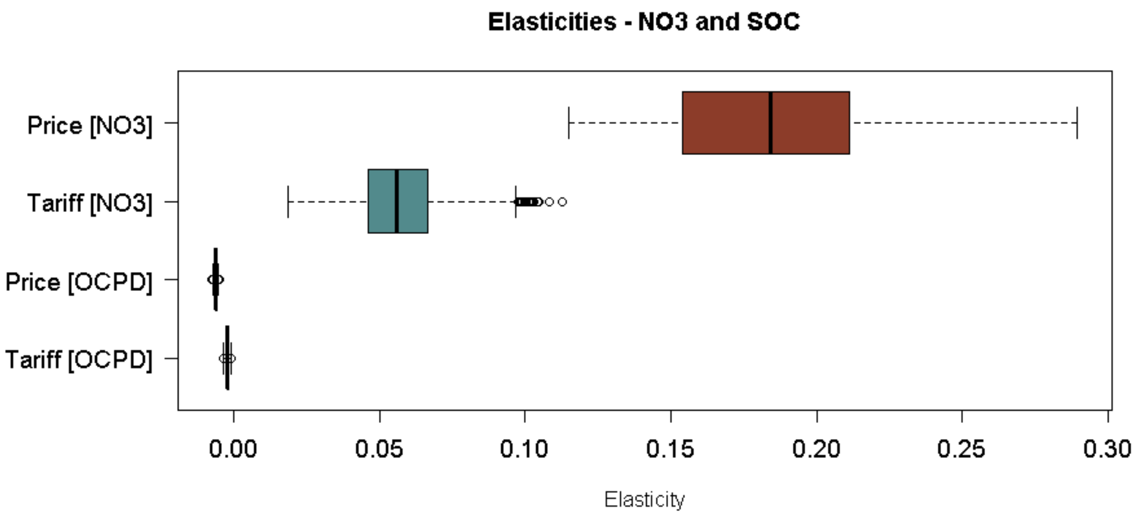

Figure 4: Elasticities of mean crop prices and tariffs for environmental outcomes
Source: own calculations

5 Conclusion

According to our model results, reducing domestic crop tariffs may increase environmental quality in Marchfeld, while global trade reductions, due to their positive effect on crop prices, are rather likely to decrease it. These effects would remain small and quite uncertain and may be dominated by the business-as-usual development of world prices. Notwithstanding, the relative impact of these measures is very marginal, especially if compared to payments that target environmentally friendly land management practices. The selected environmentally friendly management and soil conservation measures can positively affect nitrate pollution and SOC content. Hence, payments for these measures could thus be applied as ‘flanking measures’ in order to mitigate possible negative side effects due to freer trade in the Marchfeld region.

The case study analysis confirms the scientific literature that targeting environmental problems more directly will be far more effective than trying to influence important environmental variables through rather indirect measures such as trade policies (Krutilla, 2002; Whalley, 2004; WTO, 2004). Hence, it also corroborates - to some extent - the recent notion that (international) payments for ecosystem services (PES) should be used in international (trade) agreements in order to mitigate environmental degradation caused or exacerbated by international trade (Chichilnisky, 2011; Zilberman, 2011). Agri-environmental payments can be labelled as PES that focus specifically on resource modification. Such PES programs have the advantage that, under certain conditions, they may also provide desirable distributional effects for rural regions. Especially in low-income countries they could provide additional employment opportunities for landless people (Zilberman et al., 2008).

Hence, with regard to nitrate pollution and SOC content in Marchfeld, policy makers should rather focus on identifying efficient domestic policies in order to mitigate these negative externalities of agricultural production[6]. One challenge of many is hereby that agri-environmental payments (or PES programs in general) need to be in alignment with WTO trading rules. While there is no indication that a new agreement will be reached in the nearby future, there is concern that some WTO members will challenge the inclusion of environmental schemes in the green box in future negotiations (Cooper, 2005; Glebe, 2006). However, Blandford (2011) notes that although green box measures are to be reviewed in the current Doha Round, no explicit changes have been made so far in currently proposed amendments with respect to agri-environmental programs. It thus seems that as long as agri-environmental payments are effective and efficient in mitigating environmental externalities – which seems to be the case in Marchfeld – they could persist as legitimized support policies in the WTO (Glebe, 2006).

It should also be noted that high-income countries, such as Austria, usually have the institutional capacity to implement flanking measures in the case of new trade agreements. Low-income countries may lack on financial resources and institutional capacity and are thus more vulnerable if freer trade enhances negative externalities (Aggarwal, 2006; Köllner, 2011; Moon, 2011). Hence, research should particularly focus on countries that lack this ability and extent the scope of indicators (e.g. biodiversity, income distribution, soil erosion, landscape amenities).

Given the strong assumptions of the model, there is space for manifold improvements and the results should be interpreted carefully. After all, they are only able to give a quantitative **indication** of how the different trade policies may influence nitrate pollution in Marchfeld. A more holistic assessment may be needed in order to derive more conclusive results. This could be done by extending the model to the following:

- Farmers' risk behavior needs to be taken into account, especially given the high price volatilities in agricultural world markets;
- Climate change effects should be included to predict more accurate results for the foreseeable future;
- Better calibration of the model to observed data by using e.g. the method of positive mathematical programming;
- The inclusion of:
  - more environmental indicators, such greenhouse gas emissions, biodiversity and landscape amenities;
  - multifunctional indicators;
  - 'new' agricultural products in Marchfeld, for example, biomass;
  - social indicators in order to be able to make sustainable impact assessments.

It may be important to keep in mind that the "limits on current knowledge of the relevant parameters are likely to require considerable humility about the ability to capture the magnitude, or even the sign, of many important impacts [of trade liberalization]" (Martin, 2000, p. 230) and that "the dynamic and intricate nature of the problem and its complex interactions pose a challenge" (Jayadevappa and Chhatre, 2000, p. 187). But this is not to say that it is impossible. Many advances have been made in linking bio-physical simulation models with economic models. Combining such models "results in a powerful tool to reduce uncertainties in the natural and social environment and generates sufficient information to analyze economic and environmental policy implications, efficiently" (Schmid and Sinabell, N.A., p. 8).

Focus should thus be put on further improving such integrated modeling approaches for assessing (trade) policy impacts (e.g. Briner et al., 2012; Schmitz et al., 2012). While we do believe that trade policies will continue to play an important role in the future, we recognize that the focus should and will shift from traditional barriers such as tariffs and (coupled) direct payments to more implicit barriers such as technical barriers to trade. 'Hidden' trade barriers will gain on significance due to the today's comparatively low levels of traditional barriers. Research on the trade and environment issue should thus continue. We have shown that no conclusive results have been derived so far and may even remain ambiguous in regional case studies.

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[6] Of course, trans-boundary and international pollution problems, for example greenhouse gases, cannot be solved by domestic policies alone (Frankel, 2009). Increasing SOC content is considered to be a significant contribution to mitigating climate change (Freudenschuß et al., 2010).

6 Appendix

Table 5: Parameter distributions for crop prices, tariffs policy payments

Parameter			Unit	Limit		Distribution
				Lower	Upper	
Crop prices*		Winter wheat	€/t per dry matter	62.53	167.54	truncated normal distributions with $\mu = (u + l)/2$ and $\sigma = (\mu - u)/1.96$
		Durum wheat		68.99	263.42	
		Winter rye		68.54	176.59	
		Summer barley		61.37	161.67	
		Barley		55.51	148.15	
		Corn		64.94	209.77	
		Field peas		74.59	157.88	
		Winter rape seed		127.47	332.43	
		Sunflowers		148.43	325.60	
		Early potatoes		91.28	240.72	
		Potatoes		62.93	167.93	
		Sugar beet		18.99	50.62	
		Straw		48.07	74.52	
		Carrots		103.08	295.57	
		Onions		68.16	283.44	
		Green peas		197.73	300.27	
		Spinach		61.99	81.07	
Tariffs		Winter wheat	%	12.80	75.70	uniform distributions
		Durum wheat		12.80	75.70	
		Winter rye		0.00	55.60	
		Summer barley		0.00	78.90	
		Barley		0.00	78.90	
		Corn		0.00	62.50	
		Field peas		9.90	11.00	
		Winter rape seed		0.00	0.00	
		Sunflowers		0.00	0.00	
		Early potatoes		9.00	12.40	
		Potatoes		9.00	12.40	
		Sugar beet		0.00	120.20	
		Straw		0.00	0.00	
		Carrots		12.80	14.70	
		Onions		9.60	10.40	
		Green peas		9.90	11.00	
		Spinach		10.40	11.30	
Agri-environmental payments	Management	Cover crops	€/ha	0.00	130.00	Bernoulli distribution (dummy) with $p = 0.5$
		Fertilisation measure		0.00	115.00	
		Combination		0.00	245.00	
	Conservation tillage	Reduced		0.00	40.00	
		Minimum		0.00	40.00	
Support payments	Coupled crop payments			0.00	322.00	
	Single farm payment			0.00	300.00	

represent world prices transmitted to Austria ($p_w^* = p_d/(1 + t)$, where p_w is the annual world price transmitted to Austria, p_d the annual domestic price and *t* the annual tariff)

Sources: Statistics Austria (2012); BMLFUW (2002, 2008); AMA (2012); LK NÖ (2012); WTO (2012)

Table 6: Average production costs in €/ha

Crop	Maintenance	Oil	Seeds	Pesticdes	CaO	Service	Insurance
Winter barley	113.01	99.86	59.80	30.22	33.14	0.00	17.00
Corn	159.51	121.81	141.50	63.29	33.14	0.00	9.90
Carrots	344.12	229.41	435.32	294.93	0.00	272.08	0.00
Durum wheat	106.03	93.30	91.70	27.25	33.14	0.00	9.38
Fallow	40.36	34.74	45.75	0.00	0.00	0.00	0.00
Field peas	89.30	71.50	72.75	50.28	33.14	0.00	2.89
Onions	344.12	229.41	435.32	294.93	0.00	272.08	0.00
Green peas	344.12	229.41	435.32	294.93	0.00	272.08	0.00
Potatoes	589.89	212.65	572.00	187.08	33.14	0.00	0.00
Summer barley	113.01	99.86	54.17	29.54	33.14	0.00	17.00
Sugar beets	267.53	201.21	216.68	307.11	33.14	0.00	0.00
Spinach	344.12	229.41	435.32	294.93	0.00	272.08	0.00
Early potatoes	589.89	212.65	572.00	187.08	33.14	0.00	0.00
Sunflower seeds	86.79	78.50	154.70	67.86	33.14	0.00	5.18
Winter rape seeds	97.38	87.13	65.00	49.29	33.14	0.00	5.51
Winter rye	110.92	98.02	64.25	9.84	33.14	0.00	17.00
Winter wheat	117.12	103.66	63.00	39.21	33.14	0.00	17.00

Sources: BMLFUW (2008) and own data sources;

Table 7: Agri-environmental costs in €/ha

	Environmental management			Conservation tillage		Straw harvest
	cover crops	reduced fertilization	combined	reduced	minimum	
Winter rape seed	-	-	18.5	-14.1	-28.6	-
Winter barley	-	18.5	18.5	-14.1	-28.6	150
Winter rye	-	18.5	18.5	-14.1	-28.6	150
Winter wheat	-	18.5	18.5	-14.1	-28.6	150
Durum wheat	60.2	78.7	18.5	-14.1	-28.6	150
Summer barley	60.2	78.7	18.5	-14.1	-28.6	150
Field peas	60.2	78.7	-	-14.1	-28.6	-
Sunflower	60.2	78.7	18.5	-14.1	-28.6	-
Maize	60.2	78.7	18.5	-14.1	-28.6	-
Sugar beet	60.2	78.7	18.5	-6.1	-8.3	-
Potatoes	60.2	78.7	18.5	-6.1	-8.3	-
Early potatoes	60.2	78.7	18.5	-6.1	-8.3	-
Onions	60.2	60.7	-	-6.1	-8.3	-
Carrots	60.2	60.7	-	-6.1	-8.3	-
Spinach	-	-	-	-6.1	-8.3	-
Green peas	60.2	60.2		-6.1	-8.3	-

Sources: BMLFUW (2008); Schmid & Sinabell (N.A.)

Table 8: Results of the OLS regression analyses – individual values

		Regional Producer Surplus [€/ha]		Nitrate concentrations [mg/l]		SOC content [t/ha]	
Parameter		**Estimate**		**Estimate**		**Estimate**	
Intercept		-1300.06	***	44.413	***	62.8205	***
Environmental management payments		82.27	***	-18.817	***	-0.4749	***
Conservation tillage payments		28.12	***	-8.953	***	0.9334	***
Combined agri-environmental payments (environmental * conservation tillage)		-22.18	***	9.614	***	-0.3757	***
Coupled payments		250.63	***	-0.447	***	0.0088	**
Single farm payment		302.92	***				
Prices	Winter barley	0.21	***	-0.008	***	-0.0013	***
	Corn	0.57	***	-0.006	***	0.0009	***
	Carrots	0.79	***	0.010	***	0.0005	***
	Durum wheat	0.38	***	0.003	***	-0.0002	***
	Field peas	0.17	***			-0.0004	***
	Onions	0.81	***	0.016	***	-0.0007	***
	Green peas	0.35	***	-0.005	***	-0.0005	***
	Potatoes	0.90	***	0.003	***	0.0004	***
	Summer barley	0.96	***	0.005	***	-0.0003	***
	Sugar beets	9.43	***	0.085	***	-0.0025	***
	Early potatoes	0.85	***	-0.002	***	-0.0004	***
	Sunflower seeds	0.09	***	-0.003	***		
	Winter rape seeds	0.10	***	0.001	***	-0.0001	***
	Winter rye	0.22	***			-0.0002	***
	Winter wheat	2.42	***	0.017	***	-0.0006	***
	Straw	2.07	***	0.038	***	-0.0230	***
Tariffs	Winter barley	0.92	***			-0.0013	***
	Corn	0.55	***	-0.005	***	0.0006	***
	Potatoes	2.48	***				
	Sugar beets	2.04	***	0.019	***	-0.0005	***
	Winter rye	0.22	***			-0.0004	***
	Winter wheat	2.36	***	0.012	***	-0.0007	***
	Ad. R^2	*0.99*		*0.97*		*0.96*	
	N	*5000*		*5000*		*5000*	

Level of significance: *** … p<0.001; ** … p<0.01
Source: own calculations

Table 9: Elasticities for individual crop prices and tariffs

		Elasticities (nitrate concentration)		
		Minimium	**Maximum**	**Mean**
Tariffs	Corn	0.00000	-0.00977	-0.00350
	Sugar Beet	0.00001	0.07649	0.02722
	Winter wheat	0.00275	0.03023	0.01255
Prices	Winter Barley	-0.00833	-0.04135	-0.02041
	Corn	-0.00666	-0.04317	-0.01874
	Carrots	0.01876	0.08520	0.04738
	Durum Wheat	-0.00331	-0.02429	-0.01126
	Onions	0.01991	0.13405	0.06692
	Green Peas	-0.01731	-0.05225	-0.02981
	Potatoes	0.00354	0.01702	0.00854
	Summer barley	0.00542	0.02822	0.01303
	Sugar Beet	0.02852	0.13362	0.07005
	Early Potatoes	-0.00338	-0.01674	-0.00847
	Sunflowers	-0.00769	-0.03156	-0.01642
	Winter rapeseed	0.00329	0.01800	0.00811
	Winter wheat	0.01970	0.09077	0.04767
	Straw	0.03339	0.09563	0.05578

Source: own calculations

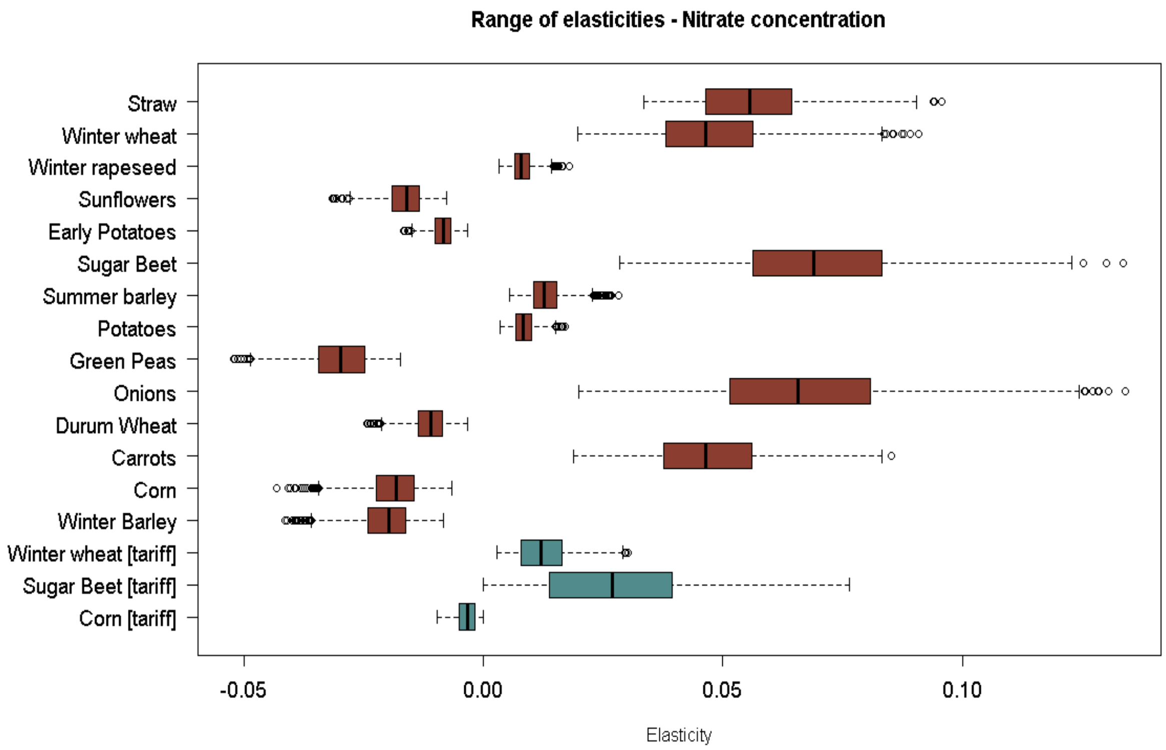

Figure 5: Range of elasticities – individual crop prices and tariffs
Source: own calculations

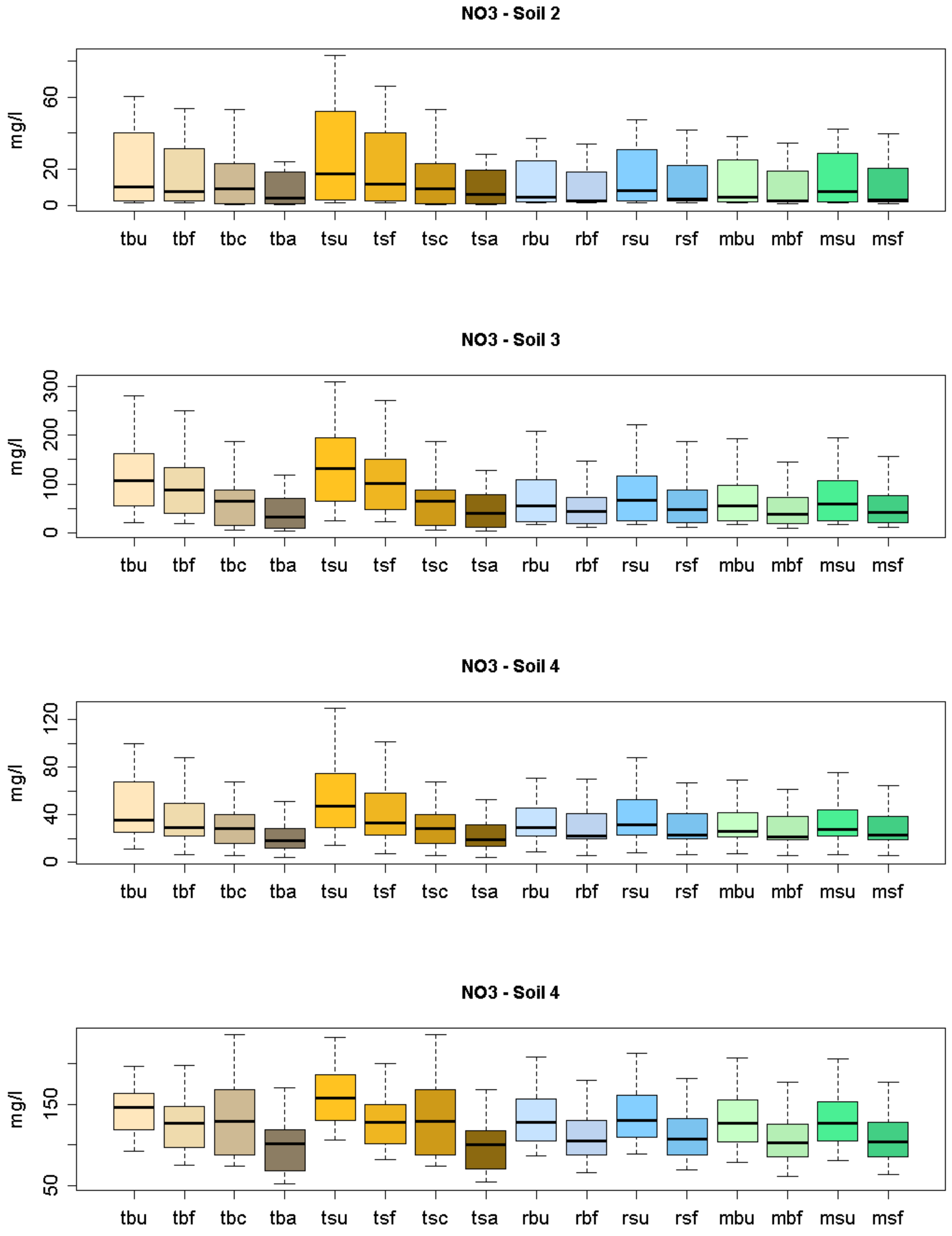

Figure 6: Variations for nitrate concentrations and SOC content on soil types 2 to 5

First letter (tillage): t … conventional tillage; r … reduced tillage; m … minimum tillage
Second letter (straw): b … no straw harvest (base); s…straw harvest
Third letter (crop): u … usual fertilizer regime; f … fertilizer splitting; c … cover crops; a … f & c

Source: own calculations

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8 Authors

Mathias Kirchner (presenting author)

Tel.: +43-1- 47654 – 3667
e-mail: mathias.kirchner@boku.ac.at

Institute for Sustainable Economic Development (INWE)
Department of Economics and Social Sciences
University of Natural Resources and Life Sciences, Vienna
Feistmantelstraße 4
A-1180 Vienna
http://www.wiso.boku.ac.at/2799.html

Doctoral School Sustainable Development
University of Natural Resources and Life Sciences, Vienna
Peter-Jordan-Straße 65
A-1190 Vienna
http://dokne.boku.ac.at/

Erwin Schmid

Tel.: +43-1- 47654 – 3653
e-mail: erwin.schmid@boku.ac.at

Institute for Sustainable Economic Development (INWE)
Department of Economics and Social Sciences
University of Natural Resources and Life Sciences, Vienna
Feistmantelstraße 4
A-1180 Vienna
http://www.wiso.boku.ac.at/2799.html