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

Mathias Kirchner and Erwin Schmid

mathias.kirchner@boku.ac.at

Institut für Nachhaltige Wirtschaftsentwicklung, BOKU
Feistmantelstraße 4, 1180 Wien

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WIE WIRKT DIE AGRARHANDELSPOLITIK AUF DIE REGIONALE UMWELT? EINE INTEGRATIVE ANALYSE FÜR DIE ÖSTERREICHISCHE MARCHFELD REGION

Abstract

It is still difficult to derive general findings and conclusions from either economic theory or empirical studies on the relationship between trade and environment. Consequently, we aim 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 statistically significant but small effects on the environment in Marchfeld. Policy makers should rather concentrate on identifying efficient domestic environmental policies, which 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

Zusammenfassung

Bis dato wurden keine umfassenden und eindeutigen empirischen Ergebnisse über das Verhältnis zwischen internationalem Handel und Umwelt publiziert. Wir versuchen zu diesem Thema beizutragen, in dem wir anhand eines integrativen Modellverbundes mögliche Umweltauswirkungen von Handelspolitiken in der Region Marchfeld untersuchen. Der Modellverbund berücksichtigt die regionale Heterogenität in der landwirtschaftlichen Produktion und Emission. Monte-Carlo-Simulationen werden angewendet, um Unsicherheiten in Bezug auf Modelparameter zu berücksichtigen und Auswirkungen von Politikszenarien zu analysieren. Die Ergebnisse zeigen, dass die Agrarhandelspolitik nur einen geringen Einfluss auf die Umweltqualität im Marchfeld hat. Politische Entscheidungsträger sollten daher effiziente nationale Umweltpolitiken entwickeln, die mit WTO Handelsregeln konform sind.

Schlüsselbegriffe

Agrarhandelspolitik, Agrarumweltmaßnahmen, Integrierte Modelanalyse, Monte-Carlo-Simulationen, Nitratverschmutzung, Organischer Bodenkohlenstoff

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 the environmental effects of agricultural trade policies have been conducted at national and global level (MALTAIS et al., 2002; COOPER et al., 2005; MORRISSEY et al., 2005; SULLIVAN and INGRAM, 2005; VAN MEIJL et al., 2006; VERBURG et al., 2009; HENSELER et al., 2009; SCHMITZ et al., 2012; BRINER et al. 2012). Despite these numerous studies on trade and environment, ZILBERMAN (2011: 29) claims that 'economists have not paid much attention to the environmental implications of trade'. Most of the studies cited above show mixed results with regard to regional environmental effects of agricultural trade policies and clearly indicate that the effects can differ largely between regions and pollutants, and that the dynamic and heterogenous effects of production should be considered in such analyses. This is why regional assessments are much better suited for the assessment of environmental effects (ERVIN, 2000; MALTAIS et al., 2002), although they 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). Overall, there seems to be a strong call in the research field to complement already available studies with site-specific regional studies (COOPER et al., 2005; HENSELER et al., 2009).

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 linear 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 East of Austria. The total area amounts to about 1,000 km² of which most are mainly arable lands (~700 km²). Crops that are predominantly produced in the region are cereals, root crops, and vegetables. Livestock production plays only a marginal role in the region and is therefore omitted in our analysis. The regional climate is characterized as semi-arid with annual precipitation sums of around 500 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, 2011). In addition, maintaining soil productivity and thus – inter alia – SOC content, may become more important in Marchfeld in the near future in order to be more resilient to likely climatic changes such as warmer temperatures, drier summers and heavy rainfall events (KLIK and EITZINGER, 2010; THALER et al., 2012; STRAUSS 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 crop, elevation, slope, soil, 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, and nitrogen leaching. EPIC simulates water, carbon and nutrient cycles and can therefore be used to analyse impacts of fertilizer intensity and other crop management measures on crop yield and the environment. Agronomic measures simulated for this case study include tillage measures (conventional, reduced and minimum), crop management measures (standard fertilisation, fertilizer splitting, cover crops, and fertilizer splitting combined with cover crops) and straw management measures (straw harvest or not). While most of these agronomic measures can be combined, we do not allow in the model to apply cover crops (and thus also fertilizer splitting combined with cover crops) 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 between 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) fertilizer splitting combined with cover crops. 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). In addition, payments are granted for historically produced crops (i.e. single farm payment).

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 always refers to both. Variable production costs per hectare (including constant fertilizer prices) have been computed using the standard gross margin catalogue (BMLFUW, 2008).

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.

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).

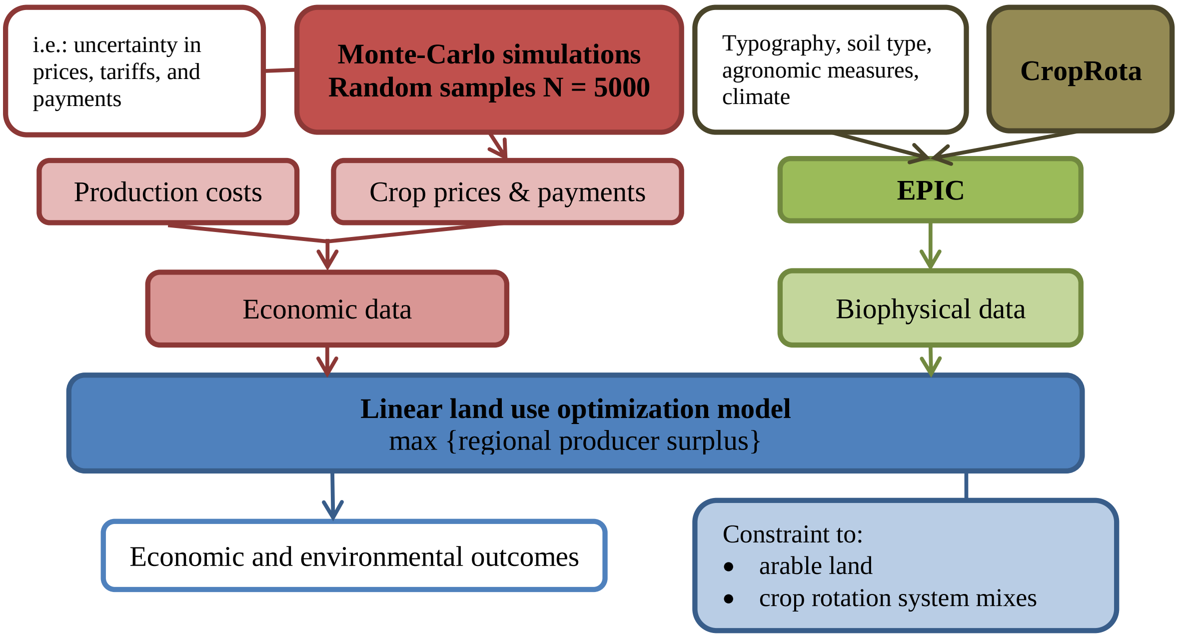

Figure 1: The integrated modelling framework

Source: own

The land use optimization model maximizes regional producer surplus subject to resource endowments and crop rotational constraints and can be described with the following set of equations:

$$\max \quad f(d,X) = \sum_c (d_c X_c) \qquad (1)$$

$$s.t. \quad \sum_c (a_c X_c) \le B_j \quad \forall j \qquad (2)$$

$$\sum_m (\theta_m r_{m,c}) \le X_c \quad \forall c \qquad (3.1)$$

$$\sum_c (X_c) \le \sum_m (\theta_m r_{m,c}) \qquad (3.2)$$

$$X_c \ge 0 \qquad (4)$$

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 *c* represents crop production choices, i.e. sub-regions, soil types, crop rotation systems, tillage systems, straw management, and 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 *r* the parameter for available crop rotation mixes, indexed by *m*). The model has been programmed with the General Algebraic Modelling System (GAMS[1]) 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). Exactly

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

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:

$$Y_E = \beta_0 + \beta_p p_{mean} + \beta_t t_{mean} + \sum_{k=1}^{n} \left(\beta_k prem_k \right) + e \qquad \forall E \qquad (5)$$

Environmental outputs *Y* (where the index *E* comprises of nitrate concentrations and SOC) are thus linearly dependent on mean crop prices p_{mean}, mean crop tariffs t_{mean} and policy payments *prem*. Three possible policy variables are represented by the index *k* and include: (1) environmental management payments; (2) conservation tillage payments and (3) a combination of environmental management and conservation tillage payments (i.e. 'combined payment'). These payments enter the regression model as dummy variables. While individual crop prices and tariffs differ in their effect and have also been assessed in the same manner, our results show that mean values can adequately represent the aggregate results.

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: 60). This approach thus allows us to assess the influence of tariff changes and agri-environmental payments on nitrate concentrations in Marchfeld.

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		

4 Results

The uncertainty in average annual values for regional producer surplus, nitrate concentrations and SOC content is illustrated in Figure 2 by the means of histograms, boxplots and density functions. The distribution of regional producer surplus is normally distributed. 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 nitrate pollution and SOC content. Hence, descriptive statistical values such as mean or standard deviation are not proper measurements for displaying such subjective uncertainty values (HELTON and DAVIS, 2000).

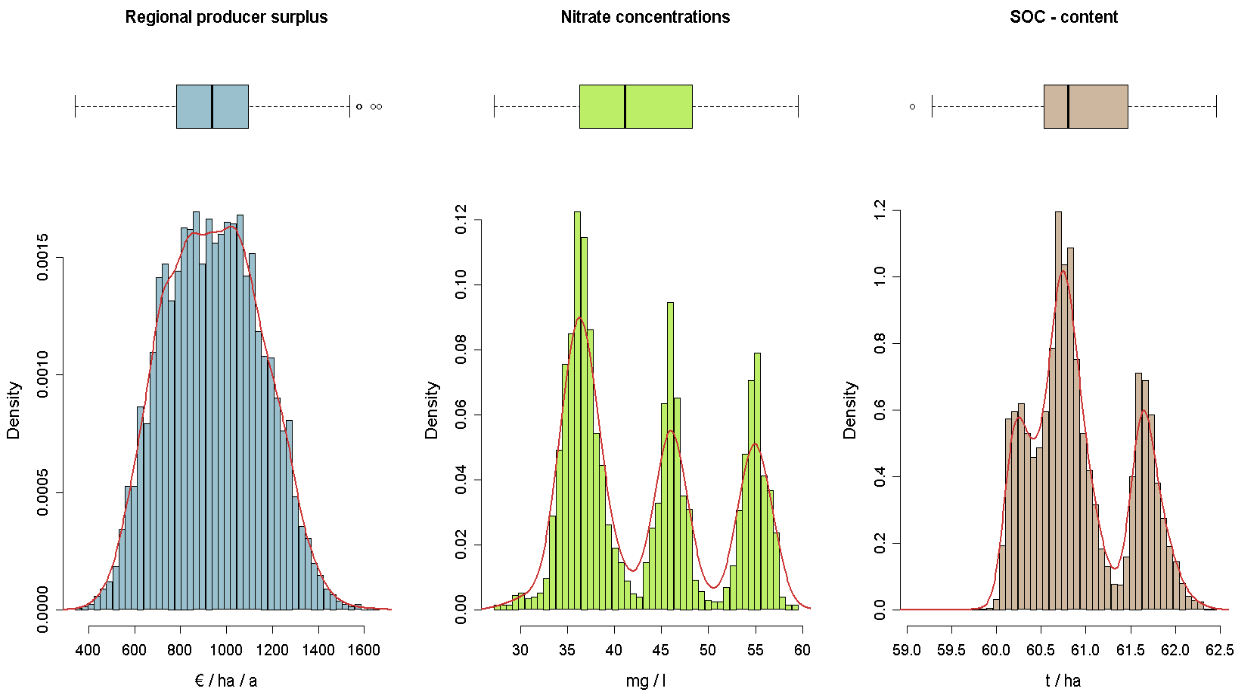

Figure 2: Distributions of model outputs

Source: own calculations

Table 2 depicts the results of the OLS regression analyses. All parameters are significant at a level of $\alpha = 0.01$, which is a threshold value typically used in sensitivity analyses (HELTON and DAVIS, 2000). The model for nitrate concentrations has an adjusted R^2 of 0.95 and is thus able to explain most of the variation in nitrate concentrations. In the case of SOC content, the model has a slightly lower fit with an adjusted R^2 of 0.88.

Table 2: Results of the OLS regression analyses

Dependent variable:	*Nitrate concentrations [mg/l]*	*SOC content [t/ha]*
Parameters	***Estimates***	
Intercept	45.591 ***	61.296 ***
Environmental management payments	-18.778 ***	-0.475 ***
Conservation tillage payments	-8.882 ***	0.937 ***
Combined payment (environmental * tillage payments)	9.546 ***	-0.375 ***
Mean crop prices	0.047 ***	-0.003 ***
Mean crop tariffs	0.088 ***	-0.005 **
Ad. R^2	*0.9489*	*0.8812*
N	*5000*	

Level of significance: *** … p<0.001; ** … p<0.01

Source: own calculations

Mean crop prices and tariffs have a statistically significant effect on nitrate concentrations and SOC content. A one unit rise in mean crop prices and tariffs (i.e. 1 € and 1 percentage point, respectively) would lead to a small increase of 0.05 or 0.09 mg/l in nitrate concentrations and a marginal decrease of 0.003 or 0.005 t/ha in SOC, respectively. Therefore, domestic tariff reductions could lead to slightly less environmental degradation, while global tariff reductions are rather likely to lead to slightly more environmental degradation due to their positive effect on world crop prices. If both policy measures are employed at the same time, the effect of domestic tariffs dominates in Austria, but becomes marginal at the aggregate level.

In contrast, payments for conservation tillage contribute not only substantially to cleaner groundwater bodies (by reducing nitrate concentrations by ca. 9 mg/l). They also have a considerably positive effect on SOC content (which increases by ca. 1 t/ha).
The highest positive impact on nitrate concentrations can be found for environmental management payments. They can lead to reductions in nitrate concentrations of almost 19 mg/l. But they seem to lead to considerable lower SOC content. A simple correlation analysis (see Table 3) reveals that these payments could give farmers a higher incentive to apply fertilizer splitting combined with cover crops which is only applicable together with conventional tillage in our analysis. Consequently they are negatively correlated with conservation tillage measures. Since, according to our EPIC simulations, conservation tillage provides much higher SOC content than conventional tillage this can explain the negative effect of environmental management payments on SOC content in the regression analysis.

Table 3: Correlation coefficients between production measures and agri-environmental payments

Management & tillage measures		*Agri-environmental payments*		
		Environmental management	**Conservation tillage**	**Combined payment**
Tillage	**Conventional**	0.70 ***	-0.70 ***	0.02
	Reduced	-0.22 ***	0.83 ***	0.30 ***
	Minimum	-0.80 ***	0.53 ***	-0.15 ***
Management	**Standard fertilization**	-1.00 ***	0.02	-0.57 ***
	Fertilizer splitting	0.90 ***	0.26 ***	0.83 ***
	Cover crops	0.18 ***	-0.04 **	0.06 ***
	Fertilizer splitting & cover crops	0.92 ***	-0.26 ***	0.24 ***

Level of significance: *** … p<0.001; ** … p<0.01

Source: own calculations

A combined payment seems to have a negative effect on nitrate pollution as well as on SOC content. A reasonable explanation can again be found by taking a look at the correlation between payments and agri-environmental measures (Table 3). If a payment is provided for both agri-environmental measures this seems to provide farmers with fewer incentives to apply fertilizer splitting combined with cover crops (than compared to only environmental management payments), thus the increase in nitrate concentrations, and it also provides less incentive to provide conservation tillage measures (than compared to only conservation tillage payments), thus the decrease in SOC content.
The influence of a combined payment on nitrate concentrations and SOC content has to be interpreted carefully. It does not mean that nitrate concentrations rise or SOC content decreases if both payments are granted compared to a situation without environmental payments. If a combined payment is granted, the single effects of environmental management and conservation tillage payments also have to be taken into account. Therefore, a combined payment mitigates the single positive effects that these payments have on nitrate concentrations and SOC content, respectively. Hence, instead of a decline in nitrate concentrations by ca. 28 mg/l (only taking into account both single effects) the actual effect of a combined payment is a decline by ca. 18 mg/l. This is only slightly less than the single effect of environmental management payments and thus explains why the left peak in the distribution of nitrate concentrations (see Figure 2) is higher than the other two (it incorporates both the effects of a single payment for environmentally friendly measures and for a combined payment). Further, the middle peak is the result of providing only conservation tillage payments, whereas the very right peak refers to a situation without agri-environmental payments.

In the case of SOC content, a combined payment almost nullifies the positive effects of conservation tillage payments. Instead of an increase by 0.46 t/ha (only taking into account both single effects), SOC content only increases slightly by 0.09 t/ha. This situation is represented by the middle peak in the distribution of SOC content, which also represents a situation without agri-environmental payments (see Figure 2). The single impacts of environmental and conservation tillage payments are reflected by the lower left peak and lower right peak, respectively.

5 Conclusion

According to the model results, changes in trade policies are most likely to have only small environmental effects in Marchfeld. The relative impact of these measures becomes almost negligible if compared to payments that target environmentally friendly land management practices. The selected agri-environmental measures can positively affect nitrate pollution and SOC content. Hence, payments for these measures easily overlay the effects of trade policies and can lead to significantly better environmental outcomes.

The case study analysis confirms the scientific literature that targeting environmental problems more directly, e.g. through payments for ecosystem service programs such as agri-environmental payments, is more effective than trying to influence important environmental variables through rather indirect measures such as trade policies (KRUTILLA, 2002; WHALLEY, 2004; WTO, 2004; CHICHILNISKY, 2011; ZILBERMAN, 2011). 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[2]. One challenge of many is hereby that agri-environmental payments 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, no explicit changes have been made so far in currently proposed amendments to the green box (BLANDFORD, 2011). Hence, 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 are thus more vulnerable if freer trade enhances negative externalities (AGGARWAL, 2006; ZILBERMAN, 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).

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[2] Of course, trans-boundary and international pollution problems, for example greenhouse gases, cannot be solved by domestic policies alone (CHICHILNISKY, 2011). Increasing SOC content is considered to be a significant contribution to mitigating climate change (FREUDENSCHUSS et al., 2010).

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