Trade policy and climate change impacts on regional land use and environment

Der Einfluss von Handelspolitik und Klimawandel auf die regionale Landnutzung und Umwelt

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Summary

We analyse the effects of trade policies and climate change on land use and environment in the Austrian Marchfeld region. An integrated modelling framework is conducted in order to account for the heterogeneity in agricultural production and emission. Our results indicate that trade liberalization dominates the effect on regional producer surplus and climate change on water use. Total nitrogen emissions increase or remain constant, depending on the scenario. Our analysis highlights the importance (i) of implementing regional water policies in a warmer and possibly drier climate, and (ii) for effective regional environmental policies under trade liberalization.

Key words: trade policy, climate change impacts, agricultural land use, agri-environmental programmes, Marchfeld

Zusammenfassung

Wir analysieren die Auswirkungen von Handelsliberalisierung und Klimawandel auf die agrarische Landnutzung und ausgewählte Umweltindikatoren in der Region Marchfeld. Es wurde ein integrativer Modellverbund eingesetzt, der die Heterogenität der landwirtschaftlichen Produktion und Emissionen abbildet. Die Modellergebnisse zeigen, dass Handelspolitiken den größten Einfluss auf die Produzentenrente haben, während die Klimawandelszenarien den Effekt auf den Wasserbedarf dominieren. Die gesamten Stickstoffemissionen können, je nach Szenario, signifikant ansteigen oder stagnieren. Die Ergebnisse

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zeigen auf, dass (i) regionale Wasserpolitiken in einem wärmeren und trockenen Klima an Bedeutung zunehmen und (ii) im Zuge einer Handelsliberalisierung effektive, regionale Agrarumweltprogramme bestehen bleiben sollten.
Schlagworte: Handelspolitik, Klimaauswirkungen, Agrarische Landnutzung, Agrarumweltprogramme, Marchfeld

1. Introduction

Since the 1990ies, there is an increasing interest in studying the environmental effects of agricultural trade policies. Current modelling analyses on trade liberalization at a global level project large shifts in agricultural production from Europe and North America to Africa, South-East Asia and South America (e.g. SCHMITZ et al., 2012). Europe may experience a shift to more extensive agricultural land use which could benefit the environment (and associated ecosystem services), but it may threaten rural livelihoods and diminish the multifunctional values of agriculture (especially if land abandonment takes place). Whether the gain in resource efficiency from liberalizing trade can compensate for the negative effects requires empirical investigations.
In addition, the effects of climate change on agricultural land use are increasingly analysed at regional to global scales (OLESEN et al., 2011). For example, higher temperatures and less precipitation may negatively affect crop yields of rainfed agriculture in the Austrian Marchfeld region (THALER et al., 2012). More irrigation may compensate for less precipitation, but comes at a higher production cost and may increase pressure on scarce groundwater resources.
Finally, computer intensive modelling exercises are increasingly used to analyse the impacts of both the socio-economic *and* climate change on land use and environment (e.g. BRINER et al., 2012). These studies indicate that considering both effects at the same time yields different results than analysing them separately and may provide some insights on the interactions between these driving forces.
The effects of trade policies and climate change may differ substantially across regions due to heterogeneity in agricultural production systems and the natural environment. Therefore, we aim to conduct a state-of-the-arte integrative assessment (IA) for the Austrian Marchfeld region by employing an integrated modelling framework

that takes into account regional heterogeneities. We consider Marchfeld to be vulnerable to trade policy changes because it is an important crop production region and sensitive to climate changes due its semi-arid climate. Furthermore, groundwater resources are negatively affected both quantitatively and qualitatively by intensive agriculture.

2. Data and method

State-of-the-art global change and land use studies increasingly apply IAs in order to better capture the complexity of human-nature interactions (ROSENZWEIG et al., 2013) and to provide better insights into the impacts of climate and policy changes (EWERT et al., 2009). Regional IAs that address both trade and climate change impacts are still rare and more information across regions is needed to be able to derive conclusions based on a broader range of heterogeneities. Therefore, we apply an integrated modelling framework by linking disciplinary data and models as well as scenarios on trade and climate change to analyse impacts on regional land use and environment (Figure 1).

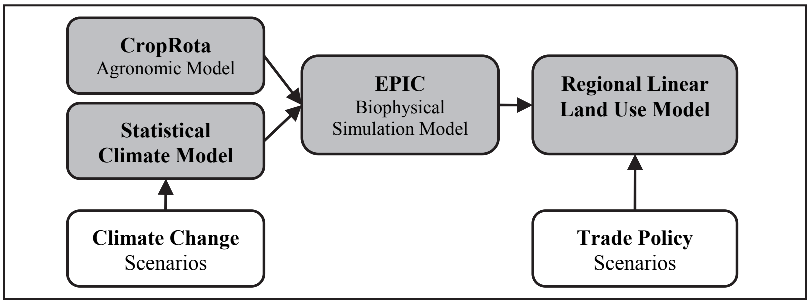

Fig. 1: Integrated modelling framework
Source: own

The biophysical process simulation model EPIC (Environmental Policy Integrated Climate) (IZAURRALDE et al., 2006; STRAUSS et al., 2012) has been employed to simulate crop yields and environmental outcomes (e.g. nitrogen emissions, water use) by natural conditions (i.e. climate, soil types and topography) as well as crop rotations and crop management measures. We account for 22 crops in the region such as cereals, corn, root crops, protein and oil crops, and vegetables. Crop rotations are derived by the CropRota model (SCHÖNHART et al., 2011) which takes into account observed crop shares, suitability scores on pairwise crop combinations, and agronomic constraints. Crop management measures comprise of different fertilization systems (standard, reduced and low) and irrigation options (rainfed and sprinkler irrigation).

The gross margins calculations include (i) average crop prices for the years 1998-2010, (ii) single farm payments, (iii) agri-environmental payments for applying reduced or low fertilization rates, (iv) variable production costs from the standard gross margin catalogue, and (v) annual capital costs of sprinkler irrigation systems. In the development of our trade policy scenarios, we make use of applied most-favourite-nation (MFN) tariffs for the years 1998-2010.

Finally, we integrate these environmental and economic datasets into a regional linear land use optimization model. This model derives optimal production choices for each scenario by maximizing the sum of average annual gross margins over all production choices (i.e. regional producer surplus - RPS) subject to regional resource endowments considering land qualities and crop rotational constraints.

We use two climate change and two trade policy scenarios for the period 2011-2040 and compare these, as well as their combinations, to a reference period that comprises of *ClimPast* (the observed climate in the past) and *BAU* (the current business-as-usual policy implementation).

Tab. 1: Reference period and Global Change scenarios

Policy parameters	**Reference**	**Scenarios**	
Climate Change	**ClimPast**	**ClimA**	**ClimB**
Period	1976-2005	2011-2040	2011-2040
Temperature	Observed	+1.5C°	+1.5C°
Annual precipitation sums	Observed	No change	-20%
Trade policies	**BAU**	**Partial**	**Full**
Domestic tariffs	Ø 1998-2011	-45%	-100%
Agri-environmental payments	ÖPUL 2007	No change	-100%
Single farm payment	Observed	-50%	-100%

Source: own.

The two climate scenarios are derived from a statistical climate model for Austria (STRAUSS et al., 2013) and serve as an important input to EPIC. In climate change scenario *ClimA*, we assume that precipitation patterns do not change, while climate change scenario *ClimB* represents a dry condition scenario with 20% lower annual precipitation sums.

The policy scenarios include a *Partial* trade liberalization scenario (e.g. the adoption of the Doha Development Agenda) and a *Full* trade liberalization scenario (i.e. full elimination of trade barriers including the elimination of agri-environmental schemes).

3. Results

3.1 Regional producer surplus

The effects of trade policies and climate change on average annual regional producer surplus (RPS) are given in Figure 2. The reference period (*BAU+ClimPast*) serves as benchmark (100%) for the other scenarios.

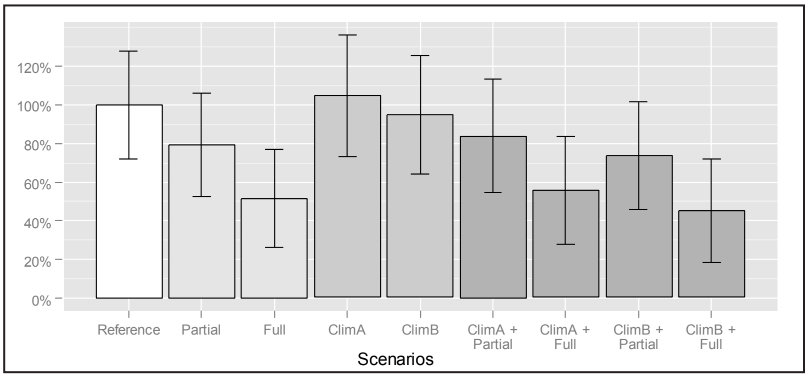

Fig. 2: The impact of scenarios on average annual regional producer surplus
Note: T-bars indicate standard deviation.
Source: own

In the trade liberalization scenarios, lower crop prices and payments reduce farmers' revenues and cause substantial drops in RPS by 21% and 48% for the *Partial* and *Full* scenarios, respectively. The outcome is more manifold for climate change. Higher temperatures and CO_2 concentration in scenario *ClimA* let crop yields raise and consequently also RPS by about 5%. Conversely, dry conditions in scenario *ClimB* trigger widespread irrigation (see section 3.3.). While irrigation increases crop yields it comes at a higher production cost, which reduces RPS by 5%. The combined effects show that *ClimB* amplifies the negative effect of trade liberalization on RPS, while *ClimA* can mitigate it to some extent. However, RPS remains substantially lower to the reference period in all combined scenarios.

3.2 Fertilization systems

Figure 3 depicts composition of fertilization systems (low, reduced, and standard) for all scenarios. In the reference period (*BAU+ClimPast*) reduced fertilization is widely applied (95%) which corresponds well to observed data in Marchfeld (93% in 2009; according to BMLFUW, 2010).

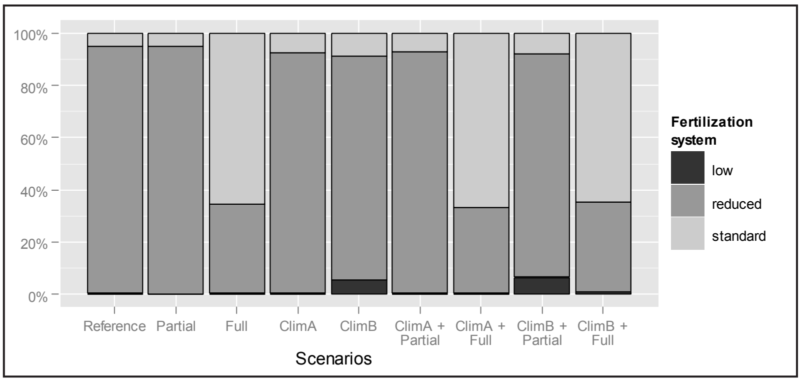

Fig. 3: The impacts of scenarios on composition of fertilization systems
Source: own

While *Partial* trade liberalisation has no significant effect on the composition of fertilization systems, *Full* trade liberalisation leads to intensification due to the abolishment of agri-environmental payments for reduced and low fertilization. The latter effect causes total nitrogen emissions to rise by ca. 11% compared to the reference period. The positive effect on crop yields in scenario *ClimA* seems to provide farmers with more incentives to switch to standard fertilization, which consequently increases nitrogen emissions by ca. 7% (in addition, EPIC outcomes show that higher temperatures lead to higher nitrogen emissions for all management measures). An increasing share of standard fertilization is shown in the dry condition scenario (*ClimB*) as well as of low fertilization, particularly on low quality land. This leads to nitrogen emissions at the same level as in the reference period. In most combined scenarios, nitrogen emissions increase significantly, except for *Partial+ClimB* where nitrogen emissions remain unchanged. The highest increase in nitrogen emissions of ca. 18% is shown in the *Full+ClimA* scenario.

3.3 Irrigation and water use

The impact of trade policies and climate change on average annual water use for irrigation is shown in Figure 4. Our model results show water withdrawals of more than 18 million m³ for the reference period. This comes close to current levels of water withdrawals in Marchfeld which range between 20 and 40 million m³ (MARCHFELDKANAL, 2012).

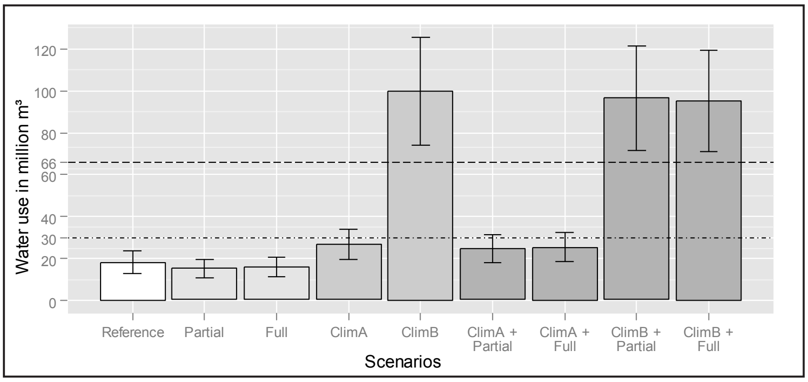

Fig. 4: The impacts of scenarios on average annual water use for irrigation
Note: T-bars indicate standard deviation; the dashed line represents the average natural groundwater recharge rate over the past 30 years (ca. 56 million m³) plus the contribution of the Marchfeldkanal (10 million m³); the dotted-dashed line indicates the amount of water use for irrigation that is likely to negatively affect the groundwater balance (ca. 30 million m³).
Source: own.

Lower crop prices in the trade liberalisation scenarios reduce the profitability of irrigation and thus lead to significantly less irrigated land. This consequently reduces water use in the *Partial* and *Full* scenarios by 16% and 13%, respectively. Climate change has a far bigger effect on water use. Higher temperatures lead to a higher demand in irrigation which increases water use by 47% in scenario *ClimA*. If the rise in temperatures is accompanied by decreasing precipitation sums, water use demand quintuples from 18 to 100 million m^3 in scenario *ClimB*. As indicated by the horizontal lines in Figure 4 this demand combined with additional groundwater withdrawals of around 22 million m^3 by municipalities and industry as well as net sub-surface run-off losses of around 14 million m^3 (MARCHFELDKANAL, 2012) far exceeds the average groundwater recharge rate of the last 30 years in Marchfeld (56 million m^3 plus 10 million m^3 through the Marchfeldkanal; NEUDORFER, 2012). Combining the scenarios reveals that trade liberalization could mitigate the adverse effect of climate change on water use to some extent. However, the relative effect of trade liberalization on irrigation becomes smaller the larger the effect of climate change (e.g. adding *Full* to *ClimB* only reduces water use by 2% compared to *BAU+ClimB*).

4. Conclusions and outlook

Our IA of trade and climate change impacts on regional land use and environment shows that there might be a need to implement regional water policies (e.g. water pricing or subsidies for more efficient irrigation systems) in order to ensure a sustainable use of water resources in the future (HEUMESSER et al., 2012). Lower crop prices alone are not sufficient to prevent unsustainable water use in dry climatic conditions. Furthermore, the effect of the *Full* trade liberalization scenario on nitrogen emissions underlines the importance of regional agri-environmental schemes. It is therefore important to ensure that effective agri-environmental schemes remain as trade friendly support measures in the current CAP post 2013 reform. Lower revenues due to trade liberalization are likely. However, the crop gross margins in the Marchfeld region are usually higher than the Austrian average such that noticeable land abandonment on marginal land might only take place in the extreme scenario *Full+ClimB* (<3%). Given the difficulty to predict land abandonment (RENWICK et al., 2013), we expect that significant changes in utilized agricultural area are unlikely in Marchfeld.

Although model results always have to be viewed with caution, we are confident in providing reliable information on the direction of change in agricultural land use and environment in the Marchfeld region. The validity of our model results is confirmed by the correspondence of the results of the reference period with the current participation rates in agri-environmental schemes and irrigation water withdrawal levels. However, our analysis did not take into account future price developments, technological development, or new production possibilities (e.g. new cultivars).

Future analyses shall aim at (a) including a wider range of crop management measures e.g. soil conservation, (b) extending the scope to the national level (Austria) to better analyse the effects on marginal areas, and (c) appling Monte Carlo simulations in order to account for uncertainty in model parameters such as crop prices. These changes are accompanied by many challenges, e.g. computational constraints due to increases in model complexity, calibration and validation of high-resolution data for many regions, data consistency, or the use of standardized data sets and scenarios to allow for inter-comparison with other studies (e.g. ROSENZWEIG et al., 2013).

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