Bottom-up and top-down modelling of climate change impacts on Austrian agriculture

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***Abstract* - Agriculture is among the economic sectors most exposed to global climate change and the impacts are likely transmitted to other economic sectors. The main objective of this article is to present the interface between a sectoral bottom-up and a Computational General Equilibrium (CGE) top-down modelling approach. This approach allows to better assess the impacts of climate change on agriculture and its inter-sectoral responses in the Austrian economy. Model results from the sectoral bottom-up model and four regional climate models show mixed results, i.e. agricultural production gains and losses depending on the climate change scenarios and NUTS-3 regions. Agricultural adaptation measures increase gains or reduce losses and are transmitted to other sectors.**

INTRODUCTION

Agriculture is among the economic sectors most exposed to global climate change. Its vulnerability, however, is determined not only by exposure in terms of directions and magnitudes of change but also by the options of the sector to adapt to a changing climate. Any impact of climate change on agriculture or its sub-sectors as well as any adaptation measures are likely transmitted to other economic sectors, either at the input or output level.

The cross-cutting nature of climate change impacts and adaptation requires an integration of climate and economic models to better assess the vulnerability of agriculture to future climates as well as its scope for adaptation. Austrian agriculture is very heterogeneous in natural conditions and farming systems, hence an integrated modelling approach is required considering bio-physical and economic inter-linkages. The economic inter-linkages require both sectoral details as well as multi-sectoral interdependencies.

The main objective of this article is to present the interface between a sectoral bottom-up and a Computational General Equilibrium (CGE) top-down modelling approach. This approach allows better assessment of the impacts of climate change on agriculture and its inter-sectoral responses in the Austrian economy. In particular, we link the agricultural production model PASMA and an Austrian CGE model based on the GTAP 7 database (GTAP, 2007). In this article we present the interface between the two models as well as preliminary results on climate change adaption from PASMA.

METHODS AND DATA

PASMA is an economic land use optimization model for Austrian agriculture (Schmid and Sinabell, 2007). It maximizes gross margins from land use and livestock activities for all Austrian NUTS 3 regions by applying positive mathematical programming methods. PASMA has its strength in the detailed description of the socio-economic, political and bio-physical systems with spatial and regional resolution. Furthermore, it is made widely consistent with the Economic Accounts of Agriculture. In course of interface building with the CGE model, PASMA provides detailed sectoral data on all major land use and livestock activities in order to replace aggregated GTAP data for three livestock and four plant production sectors in the CGE model (i.e. GRA: grain, VAF: vegetables and fruits, OSD: legumes and oilseeds, OCR: other crops including forage, RMK: dairy products, CTL: cattle, OAP: other animal production including hogs and poultry; see Figure 1). Furthermore, it accounts for climate change impacts on agriculture via spatially explicit crop yield simulations from the biophysical process model EPIC (Williams, 1995). EPIC has been applied on homogeneous response units (HRU) and regional climate data as well as with a rich set of crop management variants. Each HRU is assumed to be homogeneous with respect to soil type, slope, and altitude at a spatial resolution of one to several km². Regional climate change is considered with data from four contrasting regional climate models (RCMs) along a precipitation as well as temperature gradient.

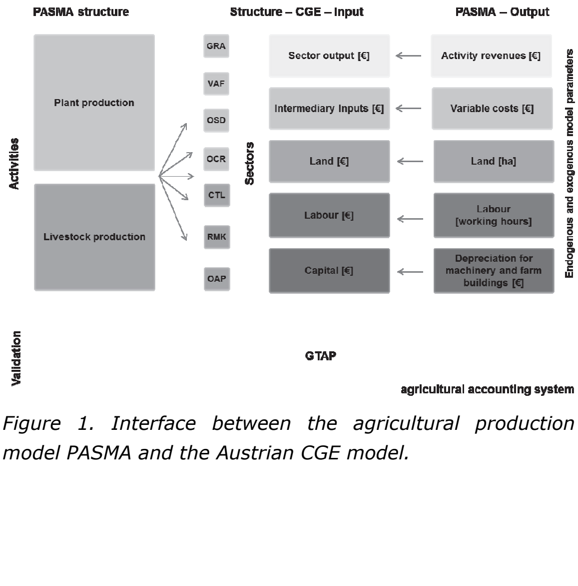

Figure 1. Interface between the agricultural production model PASMA and the Austrian CGE model.

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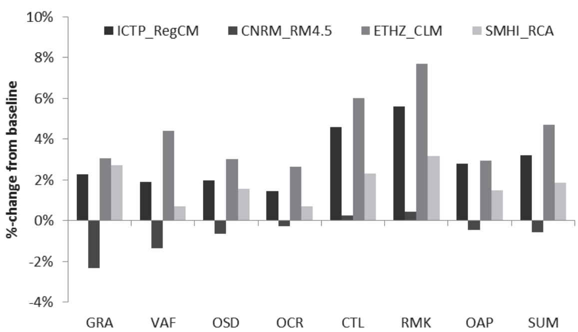
PASMA is applied considering impacts from the four RCMs and two combined scenarios for the year 2020. Furthermore, a base run for 2004 and a baseline for 2020 are modelled without climate change. In general, farmers respond autonomously to changing climate conditions depending on their awareness, risk attitudes, management skills, financial constraints and other factors. These reactions include e.g. choices on crop species and types, crop management (e.g. tillage, fertilizer application, and irrigation), or farm investments (e.g. irrigation infrastructure). In a first impact scenario (scenario 1), however, we assume a situation with only limited adaption to the changing climate, including choices on plant sowing and harvesting dates and adjustments of livestock numbers. However, no shift in technology or crop types is allowed. This should reveal the economic impacts of climate change on agriculture and its corresponding vulnerability. An autonomous adaptation scenario (scenario 2) builds on scenario 1. In PASMA, changes in crop types and land use intensity now become possible in this scenario.

RESULTS

Figure 2 shows preliminary results for scenario 1 in comparison to the baseline for the year 2020. Scenario 1 reproduces the baseline scenario with respect to land use, i.e. exactly the same crops are produced with identical crop management and output prices. However, scenario 1 accounts for climate change impacts on crop yields based on EPIC simulations. Adaptation is limited to changes in the timing of field operation (e.g. planting, harvesting) in the EPIC model as well as to livestock management including changes in feed rations and livestock numbers.



Notes: For a description of sector abbreviations, see section "Methods and Data".

Figure 2. Changes in agricultural outputs between scenario 1 and the baseline for four regional climate models in the year 2020 in %.

The agricultural output is increasing in three out of the four regional climate models leading to increasing farm producer rents. Higher grassland yields allow for higher livestock numbers and, consequently, increasing livestock production values (e.g. ETHZ_CLM). Only the regional climate model CNRM_R4.5 shows decreasing outputs for all four plant production sectors and one livestock sector.

In scenario 2 with autonomous climate change adaptation, the farm producer rents increase despite higher output levels of some sectors in scenario 1. Figure 3 compares output levels between the scenarios 1 and 2 for the RCM ICTP_RegCM. Adaptation leads to shifts in land use from grassland to cropland with corresponding decreases in livestock production. However, the farm producer rents in scenario 2 with regional climate model CNRM_R4.5 are below the baseline as well.

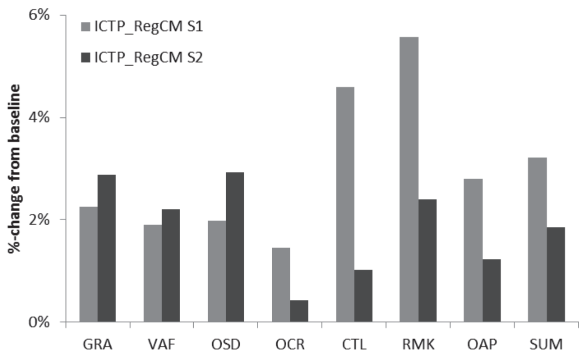


Figure 3. Changes in agricultural outputs between the baseline and the scenarios 1 (S1) and 2 (S2) with the RCM climate model ICTP_RegCM in 2020 in %.

DISCUSSION AND OUTLOOK

The results show increasing agricultural outputs and farm producer rents for three out of four RCMs. However, these aggregated results conceal that climate change impacts are much more diverse at NUTS-3 level. Interestingly, climate change adaptation for one regional climate model (Figure 3) reduces agricultural outputs due to changes in land use intensity, while it increases farm producer rents in comparison to scenario 1 without adaptation.

In a next step, the PASMA results are integrated into the Austrian CGE model to compute economy wide effects. The base year calibration has already been achieved by SAM (Social Accounting Matrix) balancing routines. Establishment of the baseline 2020 is more challenging facing the different drivers and structures of the bottom-up and top-down models.

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