Climate change impacts on European agriculture: A multi-model perspective

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***Abstract* - Climate change impacts on food production, socioeconomic developments and biofuel policies are the main challenges for the agricultural sector in the future. As the world population is expected to rise to 9 billion people until 2050, agricultural production will have to increase significantly in order to meet human food demand. Whereas integrated supply and demand side analyses of these complex issues at global level are frequent, European analyses have mostly focused on supply side effects only. Here we present and integrated supply and demand side analysis of climate change impacts on the agricultural sector from a European perspective based on a joint application of two European focused global partial equilibrium models. Results show that climate change would considerably affect agricultural supply and demand quantities as well as producer prices. Nevertheless, adaptation mechanism such as reallocation of production or intensification can help to absorb the initial climate shock so that impacts on the demand side are eventually significantly smaller. The models react consistently to climate change. Differences between the two models applied are negligible when comparing results to the output spectrum from other global partial and general equilibrium models running the same scenarios.**

Introduction to using the template

Climate change (CC) impacts on food production, socioeconomic developments (e.g. population and income growth) and biofuel policies are the main challenges for the agricultural sector in the future (Schmidhuber und Tubiello, 2007). As the world population is expected to rise to 9 billion people until 2050, agricultural production will have to increase significantly in order to meet human food demand (FAO, 2009). At the same time, CC poses a major challenge to the agricultural sector, among other, through its negative effects on agricultural productivity growth (Wheeler und Von Braun, 2013). Despite the variety of impact studies on direct effects of CC, uncertainty remains.

Here we want to supplement literature by adding an integrated supply and demand side analysis of CC impacts on the agricultural sector from a European perspective. We apply and link two European focused global models to quantify the impacts in terms of food prices and market balances up to 2050. The joint analysis is based on the two partial equilibrium models, CAPRI (Common Agricultural Policy Regionalised Impact) modelling system (Britz und Witzke, 2012) and GLOBIOM-EU, a European-focused variant of the Global Biosphere Management Model (Havlík et al., 2011). At the same time we deepen the understanding of system drivers and mechanisms and account for uncertainty as we compare the results of two different models on the same set of scenarios.

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Modelling Framework

GLOBIOM-EU is a recursive dynamic partial equilibrium land use model based on GLOBIOM integrating the agricultural, bioenergy and forestry sectors (Havlík et al., 2011). For regions outside Europe GLOBIOM-EU and GLOBIOM are identical regarding datasets used and modelling approach. However, GLOBIOM-EU has been enhanced to allow for a more detailed representation of the EU28 member countries. In the objective function, the global agricultural and forest market equilibrium is computed by choosing land use and processing activities to maximize the sum of producer and consumer surplus subject to resource, technological and policy constraints.

CAPRI is a comparative static partial equilibrium model for the agricultural sector developed for policy and market impact assessments. The core of CAPRI is based on the linkage of a European-focused supply module and a global market module. The supply module consists of independent aggregate non-linear programming models which represent all agricultural production activities and related output generation and input use at regional level. (Britz und Witzke, 2012).

Scenarios

We picked three AgMIP (Agricultural Model Intercomparison and Improvement Project) scenarios (Von Lampe et al., 2013) that appeared particularly illuminating in the context of CC: A Baseline scenario and two CC scenarios differing in the climate and crop models applied. The Baseline scenario represents present climate under a business as usual scenario (continuation of current socioeconomic trends). The CC scenarios analyse differ in the General Circulation Models (S3 - IPSL-CM5A-LR; S6 - HadGEM2-ES) which predict regional temperature and precipitation under RCP 8.5 (Representative Concentration Pathways) and the crop models (S3 – LPJmL; S6 – DSSAT) projecting CC induced changes

in average crop yields. While S3 and S6 do not differ uniformly across regions on the global level S6 is clearly more pessimistic for average crop yields.

In order to align the Baseline in the two models, GLOBIOM-EU results are used as "expert" data together with trend forecasts and other data sources to project and align CAPRI Baseline to GLOBIOM-EU Baseline. Subsequently, CAPRI is used to run the same set of CC scenarios. Finally, the results of both models are analysed and compared to each other.

Results and Discussion

Baseline scenario

In the Baseline scenario, world population increases to around 9.2 billion until 2050 which together with income growth results in a doubling of demand for agricultural products. Nevertheless, global crop prices remain stable until 2050 while they decrease by around 9% inside the EU due to productivity growth. In the livestock sector prices remain rather unchanged. In the EU increasing demand for crops is largely driven by additional biofuel consumption and livestock feeding rather than an increase in human food consumption. Productivity increases are not sufficient to meet the doubling demand for agricultural products by 2050 without expansion of agricultural area. Consequently, cropland expands globally by 14% until 2050. Inside Europe cropland continues historic trends and decreases by around 7%. Grasslands increase by 14% (stable in EU) driven by increasing demand for livestock feeding. By 2050, 140 Mha of plantation forest are established to meet rising energy demand, 13 Mha of which in the EU while forest area declines by 4%.

Climate Change Impacts on European Agriculture

CC significantly impacts global agricultural markets in the scenarios analysed (S3, S6), as overall crop yields decrease and prices increase. However, impacts depend on the climate and crop models used as well as on the economic model implementing these shocks. In both CC scenarios, agricultural prices rise compared to the Baseline without CC as productivity decreases. We decompose the exogenous climate signal into responses in terms of total yield, cropland area, production, consumption and price changes.

In Europe, the exogenous yield shock of -11% in S3 and -16% in S6 can be buffered in both models due endogenous adaptation strategies. Consequently, the exogenous CC shock translates eventually into yield declines in S3 between 7-11% and 9-14% in S6. Cropland area increases by around 4-9% in both models in S3 and 6-9% in S6 limiting further the impact of the CC shock. Production declines in S3 by 3-4% and 4-7% in S6 and consumption decreases by 3-4% in S3 and 3-5% in S6 with CAPRI predicting a smaller impact on the demand side. Average calorie consumption per capita decreases in both scenarios by around 3% inside Europe. Compared to the AgMIP results, GLOBIOM-EU is at the lower range of endogenous yield adaptation to climate change while both models are well in line for cropland expansion. Impacts on the production side are stronger compared to other models where some report increasing production under CC in Europe. Consequently, also price increases are at the upper end compared to other models.

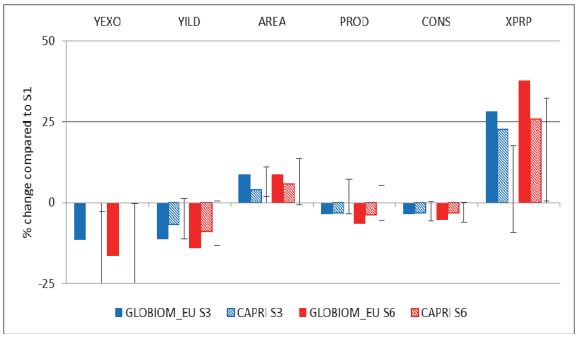

Figure 1. % change of climate change scenarios compared to the Baseline on prices (XPRP), areas (AREA), supply (PROD), demand (CONS), yields (YILD) and exogenous yield shock (YEXO) of total crop production in Europe. Upper and lower dashes represent minimum and maximum values from all models in the AgMIP exercise.

To conclude, CAPRI and GLOBIOM-EU project consistently the impacts of CC on European producer and consumers and help narrowing down the potential spectrum of impacts on agriculture. The models agree on general response patterns with other AgMIP models as adaptations on the supply side (yield, cropland area and production) are bigger compared to rather inelastic consumption behaviour. European producers and consumers will be negatively affected by climate change through decreasing productivity and increasing prices. Nevertheless, Europe may still be better off compared to other parts of the world which will be even more impacted by climate change.

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