Global Agricultural GHG Mitigation under Climate Change

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Objectives

Satisfying growing demands for food, feed, fiber, fuel and carbon sequestration from the land base is expected to become increasingly challenging over the next few decades, especially when considering the impacts of climate change on agricultural productivity. While the magnitude and even the direction of the impacts may vary across crops and regions, global climate change is expected to have substantial impacts on agricultural production throughout the world. In this study, we apply a dynamic global computable general equilibrium (CGE) model focused on the agricultural and bioenergy sectors to explore the potential effects of climate change on the costs and potential quantity of GHG mitigation available from these sectors. First, we explore GHG mitigation potential and costs under a climate policy scenario. We then use data on global agricultural productivity impacts under alternative climate scenarios from the AgMIP and ISI-MIP efforts to define the productivity shocks associated with climate change. The GHG mitigation policy scenario is then rerun in combination with the climate impacts scenario to assess the effects of including potential changes in productivity on the ability of the sector to provide GHG mitigation and its associated cost. Our findings on the implications of alternative climate change scenarios for potential GHG mitigation and cost across global regions can help inform assessments of net GHG mitigation potential across regions under future climate change scenarios.

Methods

We apply the Applied Dynamic Analysis of the Global Economy (ADAGE) model, which is a dynamic CGE model designed to examine the effects of environmental and energy policies at the international and U.S. regional levels (Ross, 2008). The model combines economic theory with empirical data to link all aspects of the economy: production, consumption, investment, trade flows, government revenue and spending, and household decisions. Energy production and consumption are represented in detail, especially new technologies for electricity generation, in order to evaluate how GHG policies may affect energy efficiency improvements, fuel switching, and demand reductions. In addition to CO_2 emissions from fossil fuels, five non-CO_2 GHG are included in the model (CH_4, N_2O, HFC, PFC, SF_6). Effects of regional or global climate policies and/or climate change impacts can be examined internationally (Calvin et al., 2015; Beach and Cai, 2013).

Several modifications and enhancements have been made to the agriculture and land use-focused version of ADAGE used in this analysis (ADAGE-ALU) in order to improve its ability to examine interactions between climate change and agricultural production. The key database used in ADAGE-ALU is the Global Trade Analysis Project (GTAP) data base version 7.1 (Narayanan and Walmsley, Ed., 2008), which comprises 57 sectors and 112 regions corresponding to the global economy in 2004. We developed a recursive dynamic version of the model to enable a more detailed regional and sectoral disaggregation of agricultural production than was computationally feasible for the intertemporal optimization version. In order to examine impacts on individual major crops, we split existing sectors in the database to create explicit sectors for individual crops such as corn, wheat, and soybeans, among others. In addition to climate impacts on crops, we include direct impacts on livestock production based on an assessment of potential impacts due to heat stress and other climate-related factors. To improve our representation of how changes in agriculture affect households, a food-processing sector is also added to the CGE model. We also added a much more detailed characterization of land use and alternative methods of characterizing land use conversion potential and costs.

Results

Our preliminary results indicate that despite continued increases in land productivity and energy efficiency in future decades, the effects of population and economic growth would dominate, leading to global increases in agricultural production, but also rising food and energy prices as well as continually growing GHG emissions in the *BAU* scenario. Comparing the climate change scenario with the *BAU* scenario, there are substantial reductions in global crop production and significant further increases in food prices, but little change in fossil fuel and biofuel production and energy prices, and only mild increases in CO_2 emissions due to land-use changes. Regions display different responses facing climate change. Relative to the *BAU* case, the implementation of a climate policy results in some cropland being afforested to store carbon, leading to a moderate rise in food and energy prices and significant GHG emission reductions. When a combined scenario with carbon policy and climate change is implemented, we see even higher reductions in global crop production and larger food price increases, along with a slightly greater reduction in GHG emissions compared with the climate change only scenario.

Conclusions

The modeling framework developed for this study represents a consistent framework for assessing the global implications of climate change impacts on the mitigation potential and associated costs for major agricultural production regions around the world. Differential impacts on productivity and capacity to adapt to changing climatic conditions are likely to lead to substantial changes in distribution of production and trade patterns as well as net GHG mitigation. From this study, we are able to examine how the global economy responds when facing multiple pressures from rising food, feed, fiber, and fuel demand under climate change in a more comprehensive and disaggregated manner than many previous studies. When designing policies, individual countries should take into consideration the overall costs and benefits associated with domestic energy, food security, and climate mitigation policy as well as the interactions of domestic policy with international policies.

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