

[Preliminary Draft – Do Not Cite or Quote]

**Assessing Climate Change Impacts on Global
Agricultural Production and Trade**

Robert H. Beach and Yongxia Cai¹

*Paper prepared for the presentation at the Sixteenth Annual Conference on
Global Economic Analysis, “New Challenges for Global Trade in a Rapidly
Changing World”, Shanghai, China, June 12-14, 2013.*

¹Beach is Director and Senior Economist and Cai is Senior Economist, Agricultural, Resource, & Energy Economics and Policy Program, RTI International, Research Triangle Park, NC.

*Address for Correspondence: 3040 Cornwallis Road, P.O. Box 12194, Research Triangle Park, NC 27709.
Emails: rbeach@rti.org; ycai@rti.org

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Abstract

Future changes in the global climate are expected to cause a wide range of impacts on agricultural production, the environment, human health and society. In this study, we apply the Applied Dynamic Analysis of the Global Economy (ADAGE) computable general equilibrium (CGE) model to examine climate impacts on agricultural production within a consistent framework. We utilize the GTAP v7.1 data base and introduce a detailed breakdown of agricultural crops. We adapt a recursive dynamic version of the ADAGE model with agriculture, biofuels, and land use linkages. ADAGE is capable of examining the impacts of climate change on the global economy and how domestic and global changes may feed through to the U.S. economy. This broad economic framework is combined with information on U.S. and international climate-change impacts from several detailed models focusing on agricultural production, including the Forest and Agricultural Sector Optimization Model with Greenhouse Gases (FASOM-GHG) and the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT). Our findings on the implications of alternative climate change scenarios for the allocation of agricultural production, markets, and trade can help inform assessments of the net benefits of GHG mitigation as well as their regional distribution.

Key Words: ADAGE, Agriculture, Climate Impacts, Recursive Dynamic.

Assessing Climate Change Impacts on Global Agricultural Production and Trade

There is general consensus in the scientific literature that human-induced climate change has taken place and will continue to do so over the next century. In particular, there is substantial evidence that these changes in climate have already begun to impact global agriculture. Agricultural producers have always faced numerous production and price risks, but forecasts of more rapid changes in climatic conditions in the future have raised concerns that these risks will increase in the future relative to historical conditions.

Methods

ADAGE is a dynamic CGE model designed to examine the effects of environmental and energy policies at the international and U.S. regional levels (Ross, 2009). 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 CO₂ emissions from fossil fuels, five non-CO₂ GHG are included in the model (CH₄, N₂O, HFC, PFC, SF₆). Effects of global policies or climate change impacts can be examined internationally.

Several modifications and enhancements have been made to the version of ADAGE used in this analysis in order to improve its ability to examine interactions between climate change and agricultural production. The key database used in this version of the ADAGE model 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 and enhance the linkage with the FASOM-GHG model, 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.

We developed baseline projections starting from 2010 through 2050. The dynamics in the model comes from growth in GDP, population, capital accumulation, labor productivity, growth in natural resource stocks, and technological changes in the energy intensive and agricultural sectors. Following Gitiaux et al. (2009), we model production of biofuels in a nested constant elasticity of substitution (CES) framework such that they utilize their respective feedstock crops along with other factor inputs. Land supply is specified as a nested constant elasticity of transformation (CET) function following Birur et al. (2008) where the land is first allocated across three cover types (cropland, pastureland, forestland) and in the second tier cropland is allocated across alternate crops. Compared to previous studies, the detailed incorporation of explicit crops in this study helps in precisely identifying the change in cropping pattern and distribution under alternative climate scenarios.

The CGE assessment of the economic impacts of these changes depends on data from other models regarding relationships between climate change and agricultural productivity. The FASOM-GHG model is an intertemporal, price-endogenous, mathematical programming model depicting the forest and agriculture sectors within multiple regions of the conterminous U.S. that incorporates productivity responses to changes in climate conditions. FASOM-GHG results from alternative climate change scenarios were used as inputs to the ADAGE model, along with international productivity impacts derived from the IMPACT model and a range of findings from the literature.

Results

Preliminary findings indicate the potential for substantial alterations in agricultural markets and global trade in agricultural commodities. Generally, there are important distributional effects as some regions are expected to be more heavily impacted than others. Different crops also face different impacts under a given scenario depending on how temperature-sensitive they are. Typically, temperate regions experience less negative productivity shocks than the tropics, leading to shifts in production and trade patterns.

Conclusions

The modeling framework developed for this study represents a consistent framework for assessing the global implications of climate change impacts on 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. Reductions in negative impacts due to GHG mitigation provide a measure of the benefits associated with alternative levels of mitigation. Our findings indicate substantial variation in economic effects, which may have important implications for public policy.

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