Modeling land use in large scale global computable general equilibrium models: Preserving physical area of land

By

Farzad Taheripour

Xin Zhao

Wallace E. Tyner

Department of Agricultural Economics

Purdue University

21st Annual Conference on Global Economic Analysis

Cartagena, Colombia

June 13-15, 2018

Modeling land use in large scale global computable general equilibrium models: Preserving physical area of land

Modeling land use in a large-scale global CGE model is a challenging and important task. While several approaches were developed to accomplish this task, some GTAP based applications used Constant Elasticity of Transformation (CET) functions to allocate land across its alternative uses (Some applications are: Golub and Hertel (2012); Hertel et al. (2010); Taheripour et al (2010); Golub et al. (2017); and Taheripour et al. (2018)). This traditional approach provides a relatively simple method to move land from one application to another application, while it implicitly takes into account the opportunity costs of land transformation (van Tongeren et al. (2017). However, it is frequently argued that this approach fails to maintain the physical accounting of land area in balance. The GTAP based applications have used some yield adjustment factors to fix this problem and maintain the physical area of land in balance. Fujimori et al. (2014) used a logit function to preserve physical area of land. More recently, van der Mensbrugghe and Peters (2016)) introduced a new approach, named Additive CET (ACET), to keep physical area of land in balance. Zhao et al. (2017) argued that "there is a direct mapping between ACET and the logit approach" developed by Fujimori et al. (2014).

In this paper, we show that while the CET functions contribute to imbalances in the physical accounting of land area, they are not the only source of imbalances in land allocation. We show that heterogeneity in the price of land (land rent) across its alternative uses generates imbalances in the physical area of land. Even with a simple market clearing condition that allows land movement across uses, when the price of land varies across uses of land that generates imbalances in the physical accounting of land area. We then show that while the ACET approach successfully maintains the physical area of land in balance, it implicitly moves away from a major and classical assumption that has been the core of GTAP comparative static analyses. The GTAP comparative static analyses traditionally assume that all endowments (measured in monetary values not physical measures) are fixed. Indeed, the GTAP static models usually assume that qo(i,r) = 0 in their closures. Here qo(i,r) represents percent change in endowment i used in region r. We show that the ACET approach departs from this classical assumption and allows qo(land,r) to shift up or down (depends on the nature of the experiment under investigation), while it maintains the physical accounting of land in balance. We show that this set up has some important welfare implications compared with the traditional approach that assumes qo(i,r)=0. We show that one can simply replicate the results of the ACET approach using the usual standard CET functions by adding a physical land constraint and a minor change in the standard GTAP closure. We call this approach as CETF

To accomplish the objective of this paper we use a simplified version of the GTAP-BIO model used by Hertel et al. (2010). We refer to this model as model A. This model uses CET approach to allocate land across uses. The model uses some productivity adjustment factors to keep the physical area of land in balance. In the absence of these productivity adjustment factors the model generates imbalances in the physical area of land. Based on this model we develop the following cases:

Case I: We remove the productivity adjustment factors from model A to calculate imbalances in the physical area of land for alternative land transformation elasticities (which represent the curvatures of the implemented CET functions used in the model) and for a given shock in the demand for corn ethanol which increases demand for cropland in corn production. We use the same shock in corn ethanol across all cases. This help us to measure the extent to which CET functions generate imbalances in the physical area of land.

Case II: We alter model A to represent a simple market clearing condition for land to allocate land across uses, again in the absence of productivity adjustment factors. We calculate land use changes and imbalances in the physical area of land. We compare the results of the first two cases to show that heterogeneity in land prices across uses is the major source of imbalances in the physical area of land.

Case III: We alter model A to only operate using the ACET approach. We repeat the simulations examined in the first case (Case I) to have the simulation results for the alternative land transformation elasticities examined in that case.

Case IV: We alter model A with the following changes to implement the CETF approach: 1) drop the productivity adjustment factors; 2) add an equation to directly maintain the physical area of land in balance; and 3) change the closure of the model to determine qo(land,r) as an endogenous variable. We repeat the simulations developed in the third case to compare the results of ACET and CETF approach.

In conclusion, using the results of the above cases we show that it is not a difficult task to maintain the area of land in balance in a large-scale global CGE model. Even with a relatively straight forward methods one can accomplish this task. However these methods should be supported with proper approaches to accurately determine the costs of land conversion across uses and also to evaluate productivity of land in transition.

Resources

- Fujimori S., et al. 2014. "Land use representation in a global CGE model for long-term simulation: CET vs. logit functions," *Food Security*, 6(5): 685–699.
- Golub A. and T. Hertel (2012). "Modeling land-use change impacts of biofuels in the GTAP-BIO framework," *Climate Change Economics*, 03(03), 1250015.
- Golub A., et al. (2017) "Global Land Use Impacts of U.S. Ethanol: Revised Analysis Using GDyn-BIO Framework," In M. Khanna and D. Zilberman (eds.), *Handbook of Bioenergy Economics and Policy*: Volume II, Natural Resource Management and Policy 40.
- Hertel T., et al. (2010) "Effects of US Maize Ethanol on Global Land Use and Greenhouse Gas Emissions: Estimating Market-mediated Responses," *Bioscience* 2010, 60:223-231.
- Taheripour F., et al. (2010) "Biofuels and their by-products: Global economic and environmental implications," *Biomass and Bioenergy*, 34(3): 278 – 289.
- Taheripour F., et al. (2018). "An Exploration of Agricultural Land Use Change at the Intensive and Extensive Margins: Implications for Biofuels Induced Land Use Change Modeling," In Bioenergy and Land Use Change, Geophysical Monograph 231, First Edition, edited by Z. Qin, U. Mishra, and A. Hastings. Hoboken, NJ: American Geophysical Union (Wiley).
- van der Mensbrugghe D., and J. Peters (2016) "Volume Preserving CES and CET Formulations," Global Trade Analysis Project (GTAP), Department of Agricultural Economics, Purdue

University, West Lafayette, IN, Presented at the 19th Annual Conference on Global Economic Analysis, Washington, DC, USA.

- van Tongeren F., et al. (2017) "Back to the Future: A 25-year Retrospective on GTAP and the Shaping of a New Agenda," *Journal of Global Economic Analysis*, Volume 2 (2017), No. 2, pp. 1-4.
- Zhao X., et al. (2017) "Modeling land physically in CGE models: new insights on intensive and extensive margins," Department of Agricultural Economics, Purdue University, West Lafayette, IN, Presented at the 20th Annual Conference on Global Economic Analysis, Washington, DC, USA. West Lafayette, Indiana, United States.