[*Preliminary Draft – Do Not Cite or Quote*]

A DYNAMIC GENERAL EQUILIBRIUM ANALYSIS OF U.S. BIOFUELS PRODUCTION

Robert H. Beach, Dileep K. Birur, Lauren M. Davis, and Martin T. Ross[1]

Paper prepared for the presentation at the Fourteenth Annual Conference on Global Economic Analysis "Governing Global Challenges: Climate Change, Trade, Finance and Development", Venice, Italy, June 16-18, 2011.

[1]Beach, Birur, Davis, and Ross are Senior Research Economists at 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; dbirur@rti.org; laurendavis@rti.org; mross@rti.org

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Abstract

With rising global interest in energy security and climate change mitigation, biofuels have gained prominent attention from researchers and policy makers. The U.S. has emerged as the leading producer of biofuels and has set a target of 36 billion gallons by 2022 under its updated renewable fuels standard (RFS2) policy. In this paper, we study the longer-term global implications of the U.S. RFS2 policy. We utilize the GTAP v7.1 data base and introduce a detailed breakdown of agricultural crops, first and second generation biofuels, and key byproducts. We adapt a recursive dynamic version of the Applied Dynamic Analysis of Global Economy (ADAGE) model developed by Ross (2009) and introduce agriculture, biofuels, and land use linkages. We construct dynamic baseline projections 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. We implement the RFS2 policy scenario in the U.S for 2025, using two alternative approaches: (i) RFS permits approach – which assumes biofuels and petroleum fuels are perfect substitutes, and (ii) Target share of biofuels in transportation fuels approach – which treats biofuels and petroleum fuels as imperfect substitutes. Because the share approach keeps the biofuels share fixed in the non-implementing regions, it does not result in dramatic changes in the rest of the world. In the permits approach, the regions with no implementation of permits will reduce or stop producing biofuels if they are not cost-competitive compared to other transportation fuels, an effect exacerbated by large-scale adoption of biofuels in countries with policies reducing the global demand for petroleum and prices of petroleum products. This rebound effect partially offsets gains associated with biofuels policies.

Key Words: Biofuels, Computable General Equilibrium, Recursive Dynamic, ADAGE.

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Biofuels, currently produced mainly from agricultural sources, have experienced an unprecedented growth in recent years. The U.S. has emerged as the leading producer of biofuels with 12.2 billion gallons of corn ethanol and 893 million gallons of oilseed-based biodiesel in 2010. The U.S. Congress has established a revised renewable fuel standard (RFS2) rule that mandates annual production of 36 billion gallons of biofuels by 2022 (USEPA, 2010). As the International Energy Agency reports, around 45 countries together produced more than 23 billion gallons of different types of biofuels for transportation in 2008. However, large-scale production of biofuels results in far-reaching intended and unintended consequences on the economy and environment. In this study, we examine the longer-term global implications of substantial increases in the volume of biofuels used in the U.S. transportation sector.

Though several studies in the recent past have analyzed economy-wide implications of biofuels, they have generally relied on either partial equilibrium models, static computable general equilibrium (CGE) models, or are specific to a single region. We adapt the Applied Dynamic Analysis of the Global Economy (ADAGE) model developed by Ross (2009) and introduce agriculture and biofuels linkages. The ADAGE model is a dynamic GCE model that has been used for analyzing the economy-wide impact of U.S. climate change policies such as the Waxman-Markey climate change bill and the American Clean Energy and Security Act of 2009.

The key data base used in this study 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. Since there are no explicit sectors on biofuels and their respective feedstock crops and by-products in the GTAP data base, we incorporated these sectors by splitting the relevant existing sectors. The final data base included new explicit sectors such as corn, soybean, rapeseed-mustard, palm-kernel, sugarcane, sugarbeet; biofuels such as corn-ethanol, wheat-ethanol, sugarcane-ethanol, sugarbeet-ethanol, soy-biodiesel, rape-biodiesel, palm-biodiesel, and major by-products of biofuels such as distiller's dried grains with solubles (DDGS), and oilseed-meal. Since the base year in ADAGE model is 2010, the modified GTAP data base was updated to the baseline year 2010 using secondary data on energy, biofuels, agriculture, and livestock sectors from the International Energy Agency and the Food and Agriculture Organization.

For introduction of agriculture and biofuels linkages, we set up the ADAGE model in a recursive dynamic framework, with the 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. The land supply is modeled in two alternate approaches. First the 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. Since CET type of land supply function is often criticized as share preserving in nature and hence not appropriate for a long run analysis, we follow Gurgel et al. (2008) and incorporate cost of land conversion from one type to another. This approach helps the model to keep track of conversion costs as well the land area converted. The transportation sector in the ADAGE model is incorporated as explicit purchased and personal vehicle transportation, where the biofuels are complemented and substituted with refined petroleum at the household level. Since the cellulosic ethanol is not commercially produced as of 2010, we introduce two kinds of feedstock, corn stover and switchgrass, as well as their ethanol derivates in model starting in 2015.

In this study, we focus on analysis of increasing U.S. biofuels consumption. Starting from the baseline 2010, we implement the 2022 U.S. biofuels mandate which includes 15 bg of corn-ethanol, 16 bg of cellulosic ethanol, and 5 bg of advanced biofuels, including biodiesel. Any import of biofuels into the U.S. subjected to implementation of the revised renewable fuel standards (RFS2) would adjust depending on the price changes and trade restrictions. Our prospective analysis indicates substantial use of crops in the biofuels sectors due to implementation of policies requiring increasing biofuels volumes. Though the increased demand for feedstock crops displaces crops away from food and feed sectors, it also substantially increases production and acreage in the U.S. and other regions of the world. The resulting increased demand for additional cropland leads to degradation of pastureland and deforestation globally, contributing to indirect land use change due to RFS implantation. We use the results from land cover change and convert to CO2E emissions based on carbon conversion factors from Houghton and Hackler (2001) and Winrock International to examine GHG emissions from indirect land use change. In the wake of rising food prices, the role of biofuels volume requirements on changes in food prices and consumption pattern across the regions are also examined.

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