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Long Run Implications of U.S. Biofuels Policies: A Dynamic General Equilibrium Analysis

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Biofuels have continued to gain momentum over the last decade due to growing worldwide interest in achieving energy security and climate change mitigation. The first generation biofuels produced mainly from agricultural sources have experienced unprecedented growth in recent years. The U.S. has emerged as the leading producer of biofuels, with 13.2 billion gallons of corn-ethanol and more than one billion gallons of biodiesel in 2012. The U.S. Congress has established a renewable fuel standard (RFS) rule that mandates annual production of 36 billion gallons of biofuels by 2022 (USEPA, 2010), which includes 16 billion gallons of second generation cellulosic biofuels. Currently, only 100 million gallons of cellulosic biofuels production capacity is under construction in the U.S. which mainly uses energy grasses and crop residue as their feedstock. As the International Energy Agency (IEA) reports, around 52 countries together produced more than 28 billion gallons of different types of biofuels for transportation in 2010. The mandates implemented in these countries would require a total production of 60 billion gallons by 2022. Large scale production of biofuels results in far-reaching intended and unintended consequences on the economy and environment. Previous studies on examining the economywide impact of biofuels have focused mainly on first generation biofuels. In this study, we examine the longer-term global implications of complete execution of U.S. RFS2 policy which includes both first and second generation biofuels.

We develop a recursive dynamic computable general equilibrium (CGE) model based on the Global Trade Analysis Project (GTAP) data base and a suite of models. The key data base used in this study is the 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 for 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 includes new explicit feedstock sectors such as corn, soybean, rapeseed-mustard, palm-kernel, sugarcane, sugarbeet, switchgrass, and corn residue. The first generation biofuels comprise 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. The second generation biofuels

include corn-stover based ethanol by biochemical process and switchgrass based ethanol by thermochemical process. For tractability, we aggregate the data base to comprise 25 regions and 37 sectors, focusing on agricultural and other sectors most likely to be directly impacted by expanded biofuels production.

We develop GDyn-E-BIO, a multi-region, multi-sector, recursive dynamic CGE model by adapting the GDyn-E-AEZ model (Golub et al., 2012) which was developed by combining comparative static versions of the GTAP-E (Burniaux and Truong, 2002) and GTAP-BIO (Birur et al. 2008; Taheripour et al. 2010) models and the recursive dynamic GDyn (Ianchovichina and McDougall, 2001). The GDyn (dynamic GTAP) model is a recursive dynamic CGE model where the agents base their decisions on adaptive expectations, with international capital mobility and endogenous capital accumulation. The dynamics in the GDyn model comes from capital accumulation, labor productivity, and other exogenous macro variables such as GDP and population growth. Following the GTAP-BIO model, we further modify the nested constant elasticity of substitution (CES) production structure of firms to allow for production of six first and two second generation biofuels by utilizing their respective feedstock crops along with other factor inputs, and complement with the petroleum products sector. We allow for substitution of all the transportation fuels in the household consumption structure with calibrated elasticity of substitution in each region.

The land supply structure follows a 18 Agro-Ecological Zone (AEZ) level nested constant elasticity of transformation (CET) function where the land is first allocated across three cover types (cropland, pastureland, forestland) and in the second tier cropland is allocated across alternate crops including switchgrass. Compared to previous studies, the detailed incorporation of explicit crops in this study helps in precisely identifying the change in cropping pattern and distribution. Based on secondary data, we develop a historical (2004-2010) baseline and forward-looking (2010-2050) baseline that includes macro-economic variables and agriculture specific features of the economy over the projected period. We validate the model by reproducing key features of the U.S. biofuels economy in 2010.

In this study, we focus on implementing the U.S. RFS2 policy. Starting from the base year 2010, we implement the 2022 U.S. biofuels mandate which includes 15 bg of corn-ethanol, 16 bg of cellulosic biofuels combining switchgrass and corn-stover feedstock, and 5 bg of

advanced biofuels combining soy-biodiesel, rape-biodiesel, palm-biodiesel, sugarcane and sugarbeet ethanol. Any import of biofuels into the U.S. subjected to RFS implementation would adjust depending on the price changes and trade restrictions. Our prospective analysis indicates substantial use of crops in the biofuels sectors due to RFS implementation. 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 implementation. 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. The role of RFS2 mandates on change in food prices and consumption pattern over the long run across the regions are also examined.

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