Global Land Use Impacts of U.S. Ethanol: Revised Analysis Using GDyn-BIO Framework

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In recent years, many partial and general equilibrium economic models, static and dynamic, have been used to analyze impacts of bioenergy on land use, food and fuel prices, and greenhouse gas emissions. One of them is a variant of computable general equilibrium (CGE) GTAP model nick-named GTAP-BIO (Birur et al. 2008). The latter is the modeling framework mandated for use in California's Low Carbon Fuel Standard (LCFS) assessments of biofuels. The GTAP-BIO model is static, yet most biofuel mandates refer to some future period in time, and without an explicit baseline, it is difficult to evaluate the relative stringency of such policies over time. In addition, presenting biofuels induced land use change analysis in the context of a dynamic baseline is far more appealing to policy makers. This paper discusses the development and application of a dynamic version of the GTAP-BIO model – GDyn-BIO – to the analysis of expanded production of U.S. corn ethanol. While other analyses of biofuels have been done with dynamic models (Gitiaux et al. 2009, Laborde 2011), this work builds on this previous research and offers analysis with the publicly available model used in Low Carbon Fuel Standard (LCFS) to further assist policy makers. Moreover, as it is explained in the abstract, many structural elements of the static version of the model have to be modified to properly represent land use change in the context of the dynamic analysis. The model keeps track of CO_2 emissions from

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fossil fuel combustion and non-CO_2 emissions. Thus, together with land use change results, it offers a framework for complete accounting of changes in emissions due to expanded production of biofuels.

The GDyn-BIO model is based on the merger of two different models: the dynamic GTAP model GDyn (Ianchovichina and McDougall 2001) and the static GTAP-BIO (Birur et al. 2008). GDyn is a multi-sector, multi-region, recursive dynamic applied general equilibrium model that extends the standard GTAP model to include international capital mobility, endogenous capital accumulation, and an adaptive expectations theory of investment. This model was used to analyze the role of global economic integration, population and income growth in determining land use change with special attention paid to consumer demands and technological progress in agriculture as drivers for supply and demand for land (Golub and Hertel 2008). The previous work, however, did not incorporate land use impacts of biofuel programs.

The GTAP-BIO (Birur et al. 2008) model is modification of GTAP-E (GTAP energy and environment model, Burniaux and Truong 2002). In GTAP-BIO, the standard GTAP sectors are dissaggregated to handle first generation biofuels and their by-products. The data base used in this work incorporates grain-based ethanol, sugar cane ethanol and oilseeds biodiesel. Soybean is separated from other oilseeds; soybean oil is separated from other vegetable oils and fats, and soybean biodiesel from other types of biodiesel (Taheripour, Golub and Tyner 2011). Biofuels co-products (Dried Distillers Grains with Solubles (DDGS) and oilseed-meals) compete with other feedstock in livestock feed use (Taheripour et al. 2011).

The starting point of the analysis is the world economy in 2004, as depicted in the version 7.0 of GTAP data base, aggregated up to 19 regions and 36 sectors. In simulations from 2004 to 2030, labor force (skilled and unskilled labor) and population growth are exogenous to the model and taken from Chappuis and Walmsley (2011). Future real GDP path is driven by differentiated assumptions about productivity growth in various sectors of the economy. Baseline path of land use from 2004 to 2030 and volumes of biofuels produced in the absence of a biofuel policy over this time horizon are critical for the analysis of land use change impacts due to biofuels mandate because the impacts are measured relative to the baseline. For this reason, special attention is devoted to various drivers of supply and demand for land and determinants of the volumes of biofuel production.

The most important driver of the demand for land is the consumer demand for food. In GTAP-BIO, the consumer preferences are represented by constant difference elasticity (CDE) consumer demand system. Comparison of the model income elasticities for food with recent econometric estimates reveals that the impact of income increase on food consumption appear to be too large in some regions. With CDE demand system, consumption goods that are luxuries at the beginning of the projection period will remain luxuries as incomes grow over the projection time horizon. For example, if meat consumption in a developing country is very sensitive to changes in income in 2004, it will remain very sensitive in 2030, even when per capita income improves relative to 2004. Thus, over time, as incomes grow in developing countries, large income elasticities for food may result in implausibly large growth in per capita food consumption, which in turn exacerbates the derived demand for land and food prices. To correct these problems, first, the demand system is recalibrated using elasticities reported in recent study by Muhhamad et al. (2011). Second, the income elasticities for food in rapidly growing low income developing economies are further modified so they more closely match the income elasticities for food in currently higher-income countries (this method is also used in Anderson and Strutt 2012).

Total factor productivity (TFP) is another key determinant of the future demand for land. For TFP growth in the agricultural sectors, we employ region and agricultural sector specific time series estimates of TFP growth reported in Ludena et al. (2007). Those authors characterize technological change as having two components: convergence (or catching up) to the technological frontier and shifts in the frontier. The regional TFP growth patterns together with sensitivity of yields to prices determine future yields in the model and location and size of land use response to the expanded biofuels production. TFP in food processing sectors is incorporated according to estimates reported in Emvalomatis, Stefanou, and Lansink (2009). Other factors determining sectoral demand for land and incorporated into the model include intensification in forestry and livestock production. In forestry, the intensification parameter is based on earlier studies. In ruminant livestock, the model allows substitution amongst feedstuffs, and between feedstuffs and land in order to reflect the empirical evidence that livestock production tends to intensify over time when land rents are rising. The latter structural element is absent from static GTAP-BIO.

On the supply side, the model incorporates revised nested constant elasticity of transformation (CET) structure of land supply. Current static version of GTAP-BIO incorporates cropland, pasture and forests in the same nest. In this dynamic analysis, the nested structure is revised whereby cropland competes with pasture within agricultural land nest, and then agricultural land competes with forests. This implementation is more consistent with empirical evidence in U.S. (Lubowski 2002).

All the factors listed above help to sketch the broad picture of land use change in the model. To attain a realistic representation of biofuels in the absence of mandate, one need to identify micro factors influencing output of relatively small (at regional economy scale) biofuel sectors. With respect to volumes of corn ethanol, such variables include price of gasoline, factors affecting corn prices, and the elasticity of substitution among liquid fuels in private consumption.

In this modeling, the calibration of the substitution parameter in the liquid fuels mix is based on econometric work of Anderson (2012).

In this dynamic analysis, the ethanol mandate comes into play in 2007. Policy scenario volumes of ethanol produced under the mandate follow historical volumes and subsequently follow those volumes reported in the FAPRI Agricultural Outlook. After 2015, the volume of U.S. corn ethanol is fixed at the mandated level. It is important to highlight that in this work baseline (without mandate) volumes of ethanol are unobservable and predicted by the model.[2]

Results suggest that in the absence of the mandate the quantity of U.S. ethanol produced within any year between 2007 and 2030 will be below the15 billion gallons/year mandated level. The amount of land needed to fulfill the mandate, as measured in hectares of additional cropland per 1000 gallons of additional ethanol, is highest in the first five years of the mandate (0.15 ha/1000ga) and then gradually diminishes over the projected time horizon. Most of this additional cropland comes from pasture. Overall, the land use change impact of the mandate modeled in the dynamic framework is smaller than the one projected with the static version of the model due to increase in yields over time.

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[2] In policy simulation, amount of U.S. ethanol is imposed exogenously.

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