Changes in the GTAP Modeling Framework and Data Base in its Application to Biofuels and Global Land Use Change

Wallace E. Tyner
James and Lois Ackerman Professor
Farzad Taheripour
Research Assistant Professor
Purdue University

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GTAP model and modifications in database

- **First generation** biofuels including: grain based ethanol, sugarcane ethanol, and biodiesel along with DDGS (co-product of grain ethanol) and meals (co-product of vegetable oil) have been introduced into GTAP database.

- **Second generation** biofuels including ethanol and biogasoline produced from corn stover, miscanthus, and switchgrass have been introduced into GTAP database.

- Several sectors have been split, and new sectors are introduced into the database to model biofuel industries and their related activities more accurately (food, feed, crude & refined vegetable oil, corn stover, dedicated crops, soybeans, rapeseed, palm oil, sorghum).
GTAP model and modifications in household demand

Household Demand for Private Goods

Energy Composite

Coal, Oil, Gas, Electricity

Non-Energy Commodities

Petro products & Biofuels composite

Petro products (Oil_Pcts)

First and Second Generations of Biofuels (G-Eth, S-Eth, Biod, M-Eth, S-Eth, Sto-Eth, M-Biog, S-Biog, Sto-Biog)
Modifications in production functions

Firm's output

Value Added & Energy

Capital-Energy Composite

Non-Energy

Intermediate Inputs

Region 1

Region r

AEZ 1

AEZ 18

Land

Labor

Resources

Capital-Non-Energy

Coal

Natural gas

Crude oil

ELECOAL

ELEN

ELNEL

ELNCOAL

ELCOOIL = 0

Petro products (Oil_Pcts)

Biofuels

Ethenol

Eth1 Eth2 Eth_Mi Eth_S Eth_Sto

Bio-gasoline

Biog_Mi Biog_Sw Biog_St

Biodiesel
Other model modifications

- Updated energy elasticities,
- Improved treatment of grains, DDGS, and oilseed meals in animal feed module,
- Separation of soybean, palm, and rapeseed from other oilseeds,
- Separation of soybean, palm, and rapeseed vegetable oils from other vegetable oils and fats,
- Separation of biodiesel production by soybean, palm, and rapeseed,
- Substitution among alternative vegetable oils.
- Incorporate cropland pasture for US and Brazil and CRP for US.
Other model modifications

- Endogenous yield adjustment for cropland pasture,
- Greater flexibility in cropland switching
- Tuning regional land transformation parameters according to recent observations,
- New land cover nesting structure with forest separated from cropland and pasture.
- Corn oil is now separated in the ethanol production process.
A nesting feed demand is introduced into GTAP

Feed new model

Others
- Other 1
- Other n

Other Crops
- Sugar Crops
- Other Agriculture

Processed Feed

Energy-Protein

DDGS-Coarse Grains
- Coarse Grains
- DDGS

Oilseed-Oilseed Meal
- Oilseeds
- Meals
Moving into forest and pastureland:

- We measure productivity of new cropland versus existing cropland with a parameter called ETA,
- In our earlier work, we used ETA=0.66 for all regions across the world (based on Field, Campbell, Lobell, 2007)

We developed a new set of regional ETAs by AEZ using a process-based biogeochemistry model (Terrestrial Ecosystem Model (TEM)) along with spatially referenced information on climate, elevation, soils, and vegetation land use data.
In TEM, the net ecosystem exchange of CO₂ between the land ecosystems and atmosphere is calculated (known as Net Primary Product - NPP).
Parameters in TEM may be specific to different vegetation types. We assigned parameters for two generic crops: C3 and C4.

To run TEM, data on atmosphere, vegetation, soil texture, and elevation at 0.5\(^0\)X0.5\(^0\) resolution from 1900 to 2000 is used.

We dropped lands not suitable for crop production.

To derive regional ETAs we compared NPP-C4 of areas with natural cover with NPP-C4 of cropland areas at AEZ level.

ETA values obtained from C4 and C3 were almost identical.

Estimated ETA values ranged from 0.42 to 1.
World Harvested Acres Total Grains, Cotton, and Oilseeds: ( Million )

- 105 million acres added in 6 years
- 2011-2012: 2,253 million acres
Oceania, Southeast Asia, and N. Africa off of a small base.

Little change in N. America or Europe
Land supply in GTAP model with dedicated crops

\( \Omega_1, \Omega_2, \text{ and } \Omega_3 \) are tuned according to actual observations over 2000-2012 (Taheripour and Tyner, 2013)
Other issues

- We now have cellulosic biofuels from corn stover, miscanthus, and switchgrass and the associated processing industries.

- Cellulosic biofuels are simulated with external shocks for each type of feedstock and biofuel (ethanol or gasoline type fuel).

- In the future, we will be exploring possible changes in the crop nesting structure to better reflect the fact that area in some crops remains relatively stable while others vary significantly.
Introducing rainfed and irrigated crops and water supply into GTAP data base

- Portman, Siebert, and Döll (2010) gridded data set is used to split GTAP crop industries into irrigated and rainfed crop categories,
- Siebert and Döll (2010) gridded data set is sued to introduce water used in irrigated crop industries into GTAP database,
- Land cover, harvested area, crop production, and water used for irrigation is introduced into version 6 GTAP data base by 18 AEZs and 20 river basins by region.
GTAP modeling framework with water resources
Other issues

➢ In recent work, we have shown that the approach used to pay for biofuel subsidies or mandates is important in measuring welfare and land use impacts.

➢ For the US, the higher crop prices, partly because of biofuels, mean that output based agricultural subsidies are no longer paid, and need to be adjusted in GTAP.

➢ Adjustments make significant changes in the GTAP simulation results, in particular for crop prices and land use.
Links to other models

- We have used GTAP land supply curves generated with biofuels shocks to provide land supply for the MARKAL model.

- MARKAL is a bottom-up energy sector model, and we modified the biofuels part to better reflect supply reality.
Evolution of land use results

- Searchinger, et al. 2008: 0.73
- Hertel, et al. 2010: 0.29
- Tyner, et al. group 1 2010: 0.22
- Tyner, et al. group 2 2010: 0.15
- Tyner, et al. group 3 2010: 0.12
- Taheripour and Tyner, 2013: 0.11
Relevant findings

- To accommodate the demand for biofuels, land can come from crop switching or from pasture and forest conversion. Results suggest switching is important.

- There is uncertainty in induced land use change, but also there is considerable uncertainty in the land use emission factors used to calculate emission from the land use change estimates.
Thank you!
Questions and Comments

For more information:
http://www.agecon.purdue.edu

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