Incorporating Biofuels in GTAP-SIMPLE-G

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Policies such as the Renewable Fuel Standard mandated biofuel use partly with the intention of reducing greenhouse gas emissions (Lade and Smith 2025), which has been particularly challenging given the direct and induced land-use changes caused by increased feedstock demand. Direct land use changes due to land-conversion for feedstock production (crops), and indirect land use changes related to market-mediated spillovers, such as increase in land prices, can further drive land conversion for feedstock production (Hertel and Tyner 2013).

These issues have been extensively investigated using a range of methods - partial equilibrium models (e.g. GLOBIOM), general equilibrium models (e.g. GTAP-BIO), supply chain life cycle analysis models (e.g. GREET), and through statistical and empirical methods (e.g. (Lark et al. 2022)). A limitation of Computable General Equilibrium (CGE) models is that they typically consider natural resource endowments to be fixed and hence cannot accommodate their supply responses. Using a spatially-explicit model that can, for example, endogenously capture a range of crop market responses to land prices or crop productivity, in relation to extensive and intensive margins with spatial granularity, can provide more accurate inputs to CGE models (Nassar et al. 2011).

The GTAP-SIMPLE-G model (Wang 2024) integrates the GTAP model (Corong et al. 2017) and the SIMPLE-G model (Simplified International Model of Agricultural Prices, Land use, and the Environment – Gridded version) (Baldos et al. 2020). SIMPLE-G is a partial equilibrium model focused on the agricultural sector well-suited to studying long-run sustainability issues. SIMPLE-G model is static and spatially disaggregated (5 arcminute). Using GTAP-SIMPLE-G represents a substantial improvement over other conventional methods of spatial downscaling CGE models due to its detailed representation of gridded production, land-use, and economic responses.

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A combined modelling approach is particularly well-suited for questions related to biofuels since it allows for capturing the wide-ranging spillovers spatially (land-use), sectorally (energy markets, livestock markets), and in terms of geographical reallocation through international trade. By extending biofuel sectors and feedstock production in GTAP-SIMPLE-G, one can examine issues such as indirect land-use changes and sourcing of feedstock at a granular scale as appropriate, while having a large sectoral representation that a CGE model like GTAP offers. This extension complements GTAP models like GTAP-BIO, which have been instrumental in analyzing market-mediated impacts of biofuel policies, by leveraging the gridded structure of SIMPLE-G and its ability to capture heterogeneity in land-use responses, production costs, and sourcing of feedstock[1].

This paper extends the GTAP-SIMPLE-G framework (Wang 2024) by explicitly incorporating biofuel sectors and spatially disaggregated feedstock linkages. While the current version of GTAP-SIMPLE-G data and model provides spatially explicit details for agricultural production, we improve on the current framework by explicitly incorporating biofuel sectors and feedstock linkages to expand the ability of the model to track market-mediated responses to biofuel demand shocks. This disaggregation allows for geographic and crop-specific heterogeneity in production structures and costs that interact with national and global biofuel demand.

This database and model extension entails the following:

- Incorporation of gridded production structure for feedstock in SIMPLE-G
- Linking gridded feedstock from SIMPLE-G with GTAP database
- Introduction of biofuel sectors in GTAP database and editing relevant equations in model

At this stage, first-generation feedstock is disaggregated in the database, expanding the GTAP crop categories to 12. Table 1 contains all the GTAP crop categories for this study and which are considered feedstock for the biofuel sector.

To test the model revisions, the following shocks will be implemented over the 2017-2050 period: (i) 1 billion-gallon increase in US consumption of soybean-based biodiesel, and (ii) 1 billion gallon increase in US consumption of corn ethanol.

[1]The GTAP-BIO model primarily models the biofuel sector as an alternative energy source and incorporates biofuel commodities through the energy input demand function. In the GTAP-SIMPLE-G model, the interest is to represent biofuel supply and choice of feedstock production directly at the gridded crop production level.

Crop Category	GTAP code	Feedstock for biofuel sector
Corn	corn	✓
Paddy Rice	pdr	
Wheat	wht	
Other cereal grains	Oth_crgr	
Sugar Crops	c_b	✓
Sorghum	sorghum	✓
Soybeans	soybeans	✓
Rapeseed	rapeseed	✓
Plant fibers	Pfb	
Vegetables and Fruit	v_f	
Other Oilseeds	Oth_osd	
Other crops	ocr	

Table 1: GTAP Crop categories

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