Global Trade Analysis Project
https://www.gtap.agecon.purdue.edu/

This paper is from the
GTAP Annual Conference on Global Economic Analysis
https://www.gtap.agecon.purdue.edu/events/conferences/default.asp

Alternative Approaches to Extend GTAP to Biofuel Crops

Authors: Woltjer, G., M. Banse, H. van Meijl, A. Tabeau

April 2007

Paper submitted for the 10th Annual GTAP Conference, Purdue University, Indiana, USA, June 7-9, 2007

ABSTRACT

The world-wide expansion in the production of biofuels is currently one of the hot topics on the agenda of agricultural and food research. On the one hand the development is welcomed as an additional source of income for farmers on otherwise saturated markets for agri-food products. One the other hand, however, there are growing concerns that with biofuels the volatility of agricultural world prices which are now linked to the development of the crude oil price will increase further.

In order to include biofuels in the GTAP model, a simplified version of the GTAP-E model is used as a starting point. Vegetable oils, corn and sugar-beet or –cane can be used as inputs in the production of biofuels in a multi-level structure in the petroleum industry. There is not explicitly added an extra sector; it is all implicit in the petrol sector model. The mechanisms in the model are illustrate by the implementation of a European biofuels directive.

1. INTRODUCTION

The world-wide expansion in the production of biofuels is currently one of the hot topics on the agenda of agricultural and food research. On the one hand the development is welcomed as an additional source of income for farmers on otherwise saturated markets for agri-food products. One the other hand, however, there are growing concerns that with biofuels the volatility of agricultural world prices which are now linked to the development of the crude oil price will increase further.

By discussion different options to extend the GTAP to biofuel crops this paper tries to contribute to this discussion. This paper describes the methodological approach to extend the GTAP-E model to biofuels production. For this extension the approach follows GTAP-E separating energy from non-energy intermediate inputs and presenting energy inputs in a capital-energy composite. The extended version of GTAP-E explicitly depicts the use of cereals, vegetable oils and sugar-beet or –cane as inputs in the production of biofuels in a multi-level structure in the petroleum activity. While the way of building-up the nesting structure is crucial for depicting the use of biofuels inputs this paper presents different alternative nests to model the use of biofuel inputs in fuel production.

One alternative to present biofuel crops is to split the non-coal inputs into gas and fuel inputs at one level, and to model the gas and fuel inputs at a second nest. Inputs for the fuel nest are presented as a composite of crude oil, vegetable oil, petroleum products and ethanol. In a final nest ethanol is modeled as a composite consisting of sugar-beet/-cane, cereals and forestry.

A second alternative separates the fuel nest into gasoline and diesel sub-nests, where diesel is a composite of crude oil, petroleum products and vegetable oil. The gasoline nest on the other hand is a composite of crude oil, petroleum products and ethanol which is again a composite of sugar-beet/-cane, cereals and forestry. The impact of the choice of CES-elasticities at the different composite nests will be illustrated by a systematical sensitivity analysis.

This extension of GTAP does not present bio-fuels, e.g. bio-diesel or bio-ethanol, as separate products for final consumption, but it enables to analyze the impact of targeted policies such as tax exemptions and obligatory blending for the petroleum sector for individual regions and countries. Blending targets will be modeled as (exogenous) shares of biofuel crops in the intermediate demand of fuel inputs in the petroleum sector. To reach the targeted input shares the paper discusses two different approaches; firstly, the provision of a price incentive (modeled as a subsidy or tax exempt) to use bio fuels and secondly the introduction of shifters in technology (adjusting input coefficients of biofuels in the aggregate fuel production).

To illustrate the impact of these different approaches the paper takes the implementation of the EU bio-fuel directive as an example for a mandatory blending obligation and illustrates the consequences of this biofuel policy on the national and international markets for agri-food products.

2. BIOFUEL MODELLING IN LEITAP

2.1. Introduction of 1st Generation of Bio-fuel Crops

The extended version of GTAP, the so-called LEITAP model is currently extended to represent the production, consumption and trade of bio-fuel products in the Eurualis project Version 2.0. A potential increasing use of renewable energy in particular biomass and biofuel will have impacts on agricultural markets including the impact on trade in agricultural raw materials as well as trade of biofuels itself. In the current version of the GTAP data base arable crops are presented only for the following products:

- Paddy rice
- Wheat
- Cereal grains nec
- Vegetables, fruits and nuts
- Oilseeds
- Sugar cane, sugar beet
- Plant-based fibres
- Other crops

These products enter the food processing industry as raw products. In the current GTAP data base Version 6.0 sectors other than the food processing demand only little agricultural products as intermediate inputs. Therefore, the introduction of 1st generation of bio-fuel crops will be modelled as 'standard' arable crops, e.g. oil-seed, cereals and sugar beet/cane. The technology to process these intermediates to final products (vegetable oil, and sugar) is already implemented in the standard model.

As the GTAP database does not record these processed products as intermediate inputs for the petroleum activity LEITAP has to be adjusted. This adjustment will affect the input-output coefficients of the petroleum activity to allow a substitution between crude oil and 'crops-oil' as well as 'crops-ethanol' to produce the final product of the petroleum activity.

Since all products (for the modelling of the 1st generation of bio-fuels) are traded a politically enforced bio-fuel production and use will have economy-wide repercussions on national and international markets.

2.2. Adjustment in the Production Structure of LEITAP

The production structure is depicted with a production tree with four different nests. The Leontief and the Constant Elasticity of Substitution (CES) functional forms are used to model the substitution relations between the inputs of the production process. In the output nest, the mix of factors and intermediate inputs are assembled together, forming the sectoral output. The functional form can be Leontief (fixed proportions) or CES while in the standard GTAP model a Leontief function is applied to describe intermediate demand, see Hertel (1997).

For the project Eururalis II (http://www.eururalis.nl/eururalis.htm) the nested CES function of the so-called GTAP-E has been adjusted and extended to model the substitution between different categories of oil (oil from bio-crops and crude-oil) in the value added nest of different industries.

The base version of GTAP represents intermediate demand in a Leontief structure (see Figure below). It is assumed that the various types of intermediate inputs are demanded in fixed proportion which are constant (or changed exogenously) and don't change according to changes in prices.
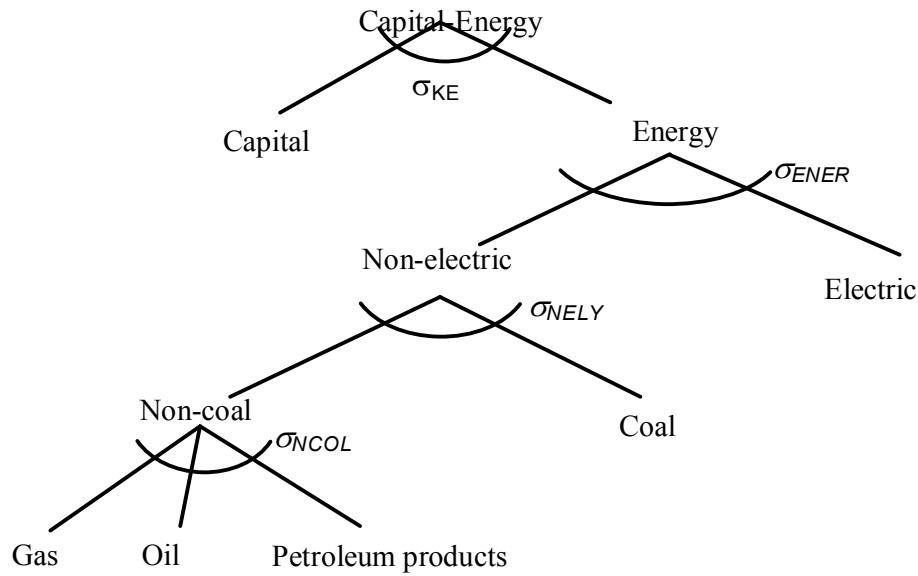
Figure 1: Standard GTAP Production Structure
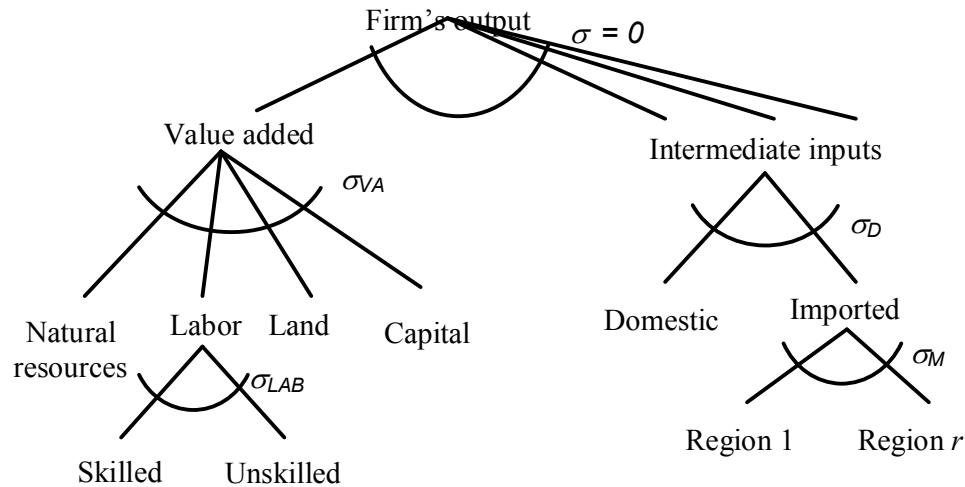
The substitution relations within the value added nest are depicted by the CES function. While labour and capital are considered mobile across sectors the Constant Elasticity of Transformation (CET) function is used to represent the adjustment of the factor land within agriculture. That is, land can only imperfectly move between alternative crop uses. The CES function is applied in the composite intermediate nest depicting the substitution between domestic and imported products. The last nest illustrates the relation between imports of the same good from different regions which is also the case for the intermediate demand of petroleum industries. The Armington approach treats products from different regions as imperfect substitutes.

For the modelling of the bio-fuel activities the intermediate demand structure is adjusted by taking into account the substitutability between different types of oil (crude oil and bio-based oils) in the production of gasoline. This approach distinguishes different types of oil inputs in a nested CES structure. Compared to the standard presentation of production technology the GTAP-E model aggregates all energy-related inputs for the petrol sector, such as crude oil, gas, electricity, coal, petrol products, under the nested structure under the value added side of the 'tree-structure' in the figure above. At the highest level the energy related inputs and the capital inputs are modelled as an aggregated 'capital-energy' composite. This 'capital-energy' composite is presented in the following figure:

Figure 2: Capital-Energy Composite in GTAP-E

Capital-Energy

σ_{KE}

Capital

Energy

σ_{ENER}

Non-electric

Electric

σ_{NELY}

Non-coal

Coal

σ_{NCOL}

Gas   Oil   Petroleum products

The extended LEITAP model presents the fuel production at Non-coal level differently compared to the approach applied under the GTAP-E model. The non-coal aggregate is modelled the following way: 1) The non-coal aggregate consists of two sub-aggregates, fuel and gas, where 'fuel' combines 'oil' and 'petroleum products' from GTAP-E. 2) Fuel is split into Gasoline/Diesel and into Ethanol, 3) Gasoline/Diesel can be produced out of crude oil, petrol products and vegetable oils while Ethanol is made out of grains and/or sugar, see following figure.

Figure 3: Input structure of biofuel production in extended LEITAP
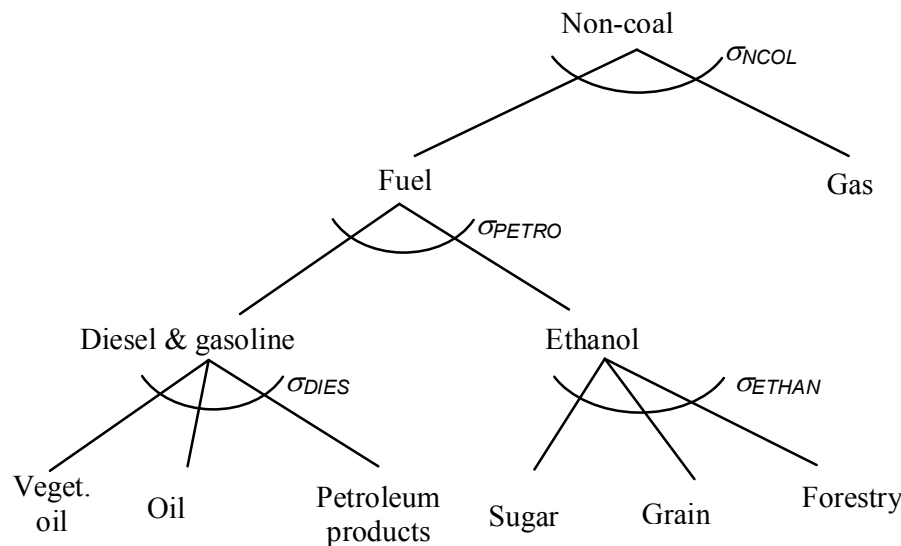
Under this approach LEITAP will be able to present an energy sector where industry's demand of intermediate strongly depends on cross-price relation of fossil energy and bio-fuel based energy. Therefore, the output prices of the petrol-industry will be amongst others a function of fossil energy and bio energy.

In addition, prices for outputs of the petroleum industry will depend on any subsidies/tax exemptions in the respective EU member states which affect the price ratio between fossil energy and bio energy. Finally, and most importantly for current EU policy, the level of demand for biofuels will be heavily determined by any enforcement of national targets through, e.g. mandatory inclusion rates. Possible mandatory inclusion rates of bio-fuels will be implemented as exogenous shifters at the level of the intermediate demand of the petroleum industries which will then lead to an increase in domestic production and/or imports of bio-fuels.

Mandatory blending, such as the EU biofuel directive, is modelled by a subsidy given to the petro industry to reduce the input prices for biofuel inputs. This subsidy is modelled as an endogenous variable which varies between EU member states. To implement this incentive instrument as a 'budget-neutral' instrument it is counter-financed by an end user tax on petrol consumption.

2.3. Introduction of 2nd Generation of Bio-fuel Crops

The presentation of the 1st generation of bio-fuel crops in LEITAP will be achieved without implementing new commodities. However, modelling the 2nd generation of bio-fuel crops requires more adjustments to the current version of LEITAP, even after implementing the 1st generation of bio-fuel crops.

For modelling the 2nd generation of bio-fuels the current GTAP data set needs to be extended by an introduction of 'new' arable or woody biomass-crops like e.g. switchgrass, forestry or by-products of primary agriculture like straw and residuals of food processing. For these new products a new technology/activity at the level of raw product and at the final product level has to be implemented. This approach follows a concept outlined in McDonald, Robinson and Thierfelder (2004).

The GTAP database does not record switchgrass or other 2nd generation commodities mentioned above as separate commodities/activities accounts; rather switchgrass is part of a larger aggregate that includes cereals and other similar field crops. Since switchgrass is not traded and it is not envisaged that switchgrass production and use will change elsewhere, there are no direct linkages with respect to switchgrass between the regions in the model. All the inter-regional effects will be indirect — as switchgrass production in one region expands, it draws land from other agricultural sectors which contract. These production changes affect trade and therefore other regions. However, on analyse the world-wide consequences of biomass production it is necessary to add these commodities and activities accounts to the database of all region covered by LEITAP.

Since switchgrass is a member of the graminae family and is harvested only once per year its input mix is similar to that of other cereal crops. However it is a perennial and therefore only requires periodic planting and reduced usage of intermediate inputs. Based on information in microeconomic studies, and in the absence of better information, one could assume in a first pragmatic approach that the primary input coefficients were the same as those for other cereals and that the intermediate input coefficients were 70 percent of those for cereals in each region. All output of biomass production will be purchased as an intermediate input by the petroleum activity. Switchgrass is only one example for 2nd generation biocrops, and it is planned to introduce also other products into LEITAP, e.g. forestry, joint products of primary agriculture and residuals of food processing.

These extensions of the LEITAP model are not available yet. However, it is planned to implement the above mentioned extension during the year 2007 within in the third phase of the EURURALIS project.

3. CONCLUSION

The introduction in LEITAP of biofuels through the nesting structure of GRAP-E seems to be a good start. But it is not more than that. A lot of problems have to be solved. One of these is the consistency of the CES nesting structure with the energy content of the different types of fuel. This implies the addition of physical data to the model. The other is the lack of dynamics of the model. Because the substitution between biofuels and crude oil is to a large extent a dynamic problem of adjustment costs, it should be a good idea to implement elements of GTAP-dyn in the model, too.

References:

McDonald, S., S. Robinson and K Thierfelder (2004). Impact of Switching Production to Bioenergy Crops: The Switchgrass Example. Paper presented on the 8th GTAP Conference in Luebeck (Germany), July 2004.

Hertel, T.W. (1997). Global Trade Analysis: Modeling and Applications (Cambridge University Press, Cambridge).