Aglink-Cosimo

Biofuel Module Documentation

OECD

Aglink-Cosimo:
A brief overview

Aglink-Cosimo is an economic model that analyses supply and demand of world agriculture. It is managed by the Secretariats of the OECD and Food and Agriculture Organization of the United Nations (FAO), and is used to generate the *OECD-FAO Agricultural Outlook* and policy scenario analysis.

Aglink-Cosimo is a recursive-dynamic, partial equilibrium model used to simulate developments of annual market balances and prices for the main agricultural commodities produced, consumed and traded worldwide. The Aglink-Cosimo country and regional modules cover the whole world, and projections are developed and maintained by the OECD and FAO Secretariats in conjunction with country experts and national administrations. Several key factors or assumptions are as follows:

- World markets for agricultural commodities are competitive, with buyers and sellers acting as price takers. Market prices are determined through a global or regional equilibrium in supply and demand.
- Domestically produced and traded commodities are viewed to be homogeneous and thus perfect substitutes by buyers and sellers. In particular, importers do not distinguish commodities by country of origin as Aglink-Cosimo is not a spatial model. Imports and exports are nevertheless determined separately. This assumption will affect the results of analysis in which trade is a major driver.
- Aglink-Cosimo is a "partial equilibrium" model for the main agricultural commodities. Non-agricultural markets are not modelled and are treated exogenously to the model. As non-agricultural markets are exogenous, hypotheses concerning the paths of key macroeconomic variables are predetermined with no accounting of feedback from developments in agricultural markets to the economy as a whole.
- Aglink-Cosimo is recursive-dynamic. Thus, each year is modelled over the projection period and depends on the outcome of previous years. Aglink-Cosimo models ten years into the future.

Aglink-Cosimo Biofuel documentation

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SUMMARY

Amongst the major developments of the 2017 update of the Aglink-Cosimo's biofuels module was the demand and supply equations template, and its application to the countries covered by the model. In addition to defining the variables, equations, and assumptions used in the biofuels module, this document describes the following updates:

- Endogenous transportation fuel demand system
- Inclusion of high blend biofuels demand
- Linkage between the biofuels modules and the other components of the Aglink-Cosimo model

In addition to generating baseline outlook reports, the updated biofuels module will be used to simulate policies in the context of global climate change mitigation scenarios. Even though the Aglink-Cosimo model assumes the world crude oil price exogenously, the inclusion of an endogenous domestic fuel-use (gasoline and diesel) equation within the biofuels module will link the energy markets to the agricultural market within the broader Aglink-Cosimo modelling framework. It will allow the biofuels module to simulate different ethanol supply and utilization pathways which are driven by overall domestic fossil fuels consumption. After testing multiple functional forms, the log-log model was chosen to model country-specific domestic gasoline and diesel demands using the following equation:

$$\log F_{q,c,t} \quad = \quad k_0 + k_1 * \log CP^{F}{}_{q,c,t} + k\alpha_2 * \log CP^{BF}{}_{q,c,t} + k_3 * \log I_{c,t} + k_4 * V_{c,t} + \varepsilon^{BF}{}_{q,c,t}\ ; \qquad (1)$$

where,

$F_{q,c,t}$ = the per capita q (gasoline or diesel) type of fuel use in country c and year t

$CP^{F}{}_{q,c,t}$ = the consumer price of q (gasoline or diesel) type of fuel in country c and year t

$CP^{BF}{}_{q,c,t}$ = the biofuels (ethanol or biodiesel) consumer price associated with q (gasoline or diesel) type of fuel use in country c and year t

$I_{c,t}$ = the per capita GDP in country c and year t

$V_{c,t}$ = vehicle fuel efficiency in country c and year t

k_0, and k_1, k_2, k_3, k_4 = the intercepts and slope coefficients

$\varepsilon_{q,c,t}$ = the corresponding error terms.

The endogenous fuel equations play an important role in the Aglink-Cosimo model when the latter is used to simulate different (extreme) crude oil price scenarios. These equations trace the changes in the mandate-driven complementary biofuels use.

As the use of biofuels is driven by mandates – which in most countries are introduced in terms of percentage of the total fuel use – this means changes in fossil fuel use could change how biofuels are used. It is thus important to trace the total gasoline and diesel use within the biofuels module. The adoption of these endogenous fuel-use equations can capture both the compliment and substitution effects between fossil fuels and biofuels, even though in the broader Aglink-Cosimo modelling framework the domestic gasoline and diesel use is derived from the exogenous world crude oil price.

In order to capture the substitution effects, the use of high blend biofuels ($HB^{BF}{}_{q,c,t}$) in type of fossil fuel q in country c and year t is introduced as an exponential function of biofuels ($CP^{BF}{}_{q,c,t}$) and fossil fuel ($CP^{F}{}_{q,c,t}$) price ratios (as shown below).

$$HB^{BF}{}_{q,c,t} \quad = \quad HS^{BF}{}_{q,c,t} * F_{q,c,t} / EE^{BF} \qquad (2)$$

$$HS^{BF}_{q,c,t} = \frac{1}{(1+\exp(4*\kappa*(CP^{BF}_{q,c,t}/CP^{F}_{q,c,t} - EE^{BF})} \qquad (3)$$

where

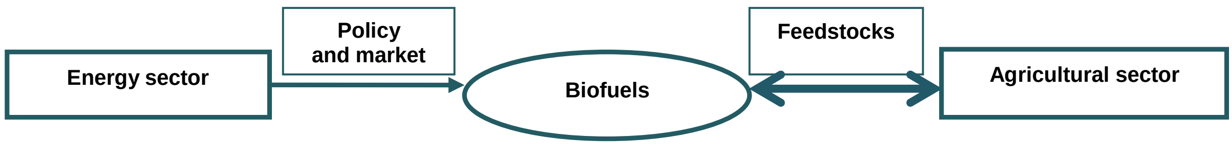
$HS^{BF}_{q,c,t}$ = share of high blend biofuels (ethanol or biodiesel) in type of fossil fuel q in country c in year t

EE^{BF} = the energy equivalent of biofuels to fossil fuels

and all other variables defined at an earlier stage.

Significant improvement were made to the supply side of the biofuels module. The most important is re-establishing the link between the biofuels module and the other components of the Aglink-Cosimo model.

Linkage between the energy, biofuels and agricultural sectors



The production of biofuels (ethanol and biodiesel) derived from each type of feedstock ($FS^{BF}_{q,i,c,t}$) are modelled separately, using the following equation:

$$\log FS^{BF}_{q,i,c,t} = \nu_0 + \nu_1 * \log RM^{BF}_{q,i,c,t} + \nu_2 * \log RM^{BF}_{q,i,c,t-1} + \nu_3 * \log RM^{BF}_{q,i,c,t-2} + \nu_4 * \log RM^{BF}_{q,i,c,t-3} + \nu_5 * \log FS^{ET}_{q,i,c,t-1} + \varepsilon^{BF}_{q,i,c,t} \quad (4)$$

where

$RM^{BF}_{q,i,c,t}$ = the profit derived from utilising feedstock i for the production of biofuels (ethanol or biodiesel) to be blend in type of fossil fuel q in country c and year t.

The $RM^{ET}_{q,i,c,t}$ is derived based on the following identity:

$$RM^{BF}_{q,i,c,t} = \frac{PP^{BF}_{q,i,c,t} + DP^{BF}_{q,i,c,t} + VL^{BF}_{q,i,c,t}}{PI^{BF}_{q,i,c,t}} \quad (5)$$

where

$PP^{BF}_{q,i,c,t}$ = the biofuels (ethanol or biodiesel) producer price in country c in year t

$DP^{BF}_{q,i,c,t}$ = direct government support for biofuels (ethanol or biodiesel) production tied with the use of feedstock i in country c and year t

$VL^{BF}_{q,i,c,t}$ = the value of by-products derived from the use of feedstock i in biofuels (ethanol or biodiesel) production in country c and year t

$PI^{BF}_{q,i,c,t}$ = production cost index associated with the use of feedstock i in the production biofuels (ethanol or biodiesel) in country c and in year t

$\varepsilon^{BF}_{q,i,c,t}$ = the corresponding error term.

$PI^{BF}_{q,i,c,t}$ depends on feedstock i's producers price ($PP^{i}_{c,t}$) as shown below:

$$PI^{BF}_{q,i,c,t} = f(PP^{i}_{c,t}) \quad (6)$$

The purpose of including separate production functions specific to feedstocks is to track changes in greenhouse gas emission as well as the direct and indirect consequences of changes in land use due to the use of a variety of food and non-food-based feedstocks in the production of biofuels.

1. INTRODUCTION

The biofuels component of the Aglink-Cosimo model is a structural economic model that analyses the world supply and demand for ethanol and biodiesel. The biofuels module is a recursive dynamic, partial equilibrium model used to simulate the annual market balances and price for the production, consumption and traded quantity of ethanol and biodiesel worldwide. This model is completely integrated with the cereals, oilseeds and sugar component of the Aglink-Cosimo model. The production of biofuels drives the additional demand for agricultural commodities, in particular coarse grains, vegetable oil, and sugar.

The model is jointly managed by the Secretariats of the Organisation for Economic and Co-operation and Development (OECD) and the Food and Agriculture Organization (FAO) of the United Nations. The Aglink-Cosimo model is used each year to generate the commodity chapters of the *OECD-FAO Agricultural Outlook.* The biofuels module analyses several biofuel-related forward-looking policy scenarios. The ability to capture the interaction between biofuels and agricultural commodities across countries is a major strength of this module; it allows policy makers and analysts to track unintended consequences of biofuels policies on other agricultural sectors.

The major characteristics of the biofuels module are as follows:

- The ethanol and biodiesel markets worldwide are assumed to be competitive, with buyers and sellers behaving as price takers. Domestic and international ethanol and biodiesel prices are determined by solving the equilibrium demand and supply of each type of biofuel.
- The biofuels module is nonspatial; that is, ethanol and biodiesel are assumed to be homogeneous and that countries which import ethanol and biodiesel do not distinguish biofuels based on the country of origin.
- Like other components of the Aglink-Cosimo model, the biofuels module is recursive-dynamic. In each projection period, the model solved is based on the outcome of the previous year. The model simulates ten years of outcomes onto the future, referred to as the medium-term outlook.
- Ethanol and biodiesel are assumed to be mutually exclusive; as such, there is no substitution effect between the uses of these two fuels.
- Non-fuel use of ethanol and biodiesel are not modelled and are treated as exogenous.

The major revisions made to the biofuels module in 2017 include maintaining uniformity in the ethanol and biodiesel modules across country modules so that the biofuels module was easily traceable. Within the constraints of this uniformity (template framework), the biofuels module captures individual domestic country-specific mandates, tax, subsidies, and trade policies. The updated biofuels module combines all countries covered by the Aglink and Cosimo models, and will be updated and maintained by the OECD.

2. MODEL CHARACTERISTICS

The biofuels module is a part of the Aglink-Cosimo model. The Aglink-Cosimo framework is traditionally based on the demand and supply of a commodity as driven by market conditions, with the exception of a few countries and commodities. There are important differences for biofuels. Irrespective of the relative biofuels prices over crude oil prices, there are minimum levels of demand for biofuels as this is strongly driven by policies. The specific use of biofuels is driven by the domestic ethanol and biodiesel use mandates, referred to here as domestic mandates. The forward-looking biofuels market outlook developed by the Aglink-Cosimo model relies heavily on the country-specific domestic biofuels use mandate assumptions, which further drives production of biofuels and feedstock demand.

The updated biofuels module includes a template model for the following countries: Argentina, Australia, Brazil, Canada, China, European Union, Japan, Korea, Mexico, New Zealand, Norway, Russian Federation, Switzerland, United States, Colombia, Chile, India, Indonesia, Malaysia, Paraguay, Philippines and Thailand.). Ethanol and biodiesel are modelled separately for each country. The new biofuels module also includes a separate demand and supply for ethanol and biodiesel for the Rest of the World (ROW).

The Aglink-Cosimo model has cereals, oilseeds and oilseeds products, livestock, dairy and dairy products, cotton, sugar, and biofuels modules. Each module is linked to the others; for example, livestock and cereals production compete for land, while herd size in the livestock module depends on the dairy component. The biofuels module is linked to the other components of the Aglink-Cosimo model mainly via the food-based feedstocks demand which includes, amongst other commodities, maize, sugar, wheat, and rice (Table 2). In the previous version of the biofuels module, the demand for non-food-based feedstocks was assumed to be exogenous. However, along with the many other additions to the new biofuels module, the inclusion of endogenous non-food-based feedstock use allows the Aglink-Cosimo model to analyse scenarios related to direct and indirect land use changes. As such, modelling the use of dedicated energy crops for ethanol/ biodiesel production is an addition to the lists of commodities that Aglink-Cosimo simulates.

Policies regulate biofuels demand, which in turn drives domestic production and increases feedstock demand. Figure 1 shows the links between the biofuels module and other components of the Aglink-Cosimo model. The biofuels module is linked through the feedstocks use equations to the rest of the Aglink-Cosimo model. The food-based feedstocks used for biofuel production directly compete with the livestock industry as an increase (decrease) in their demand regulates the feedstock market and further drives the livestock prices. The biofuel module serves as a direct link between the energy and agricultural sectors.

Figure 2 shows how the linkage between the energy, biofuels and agricultural sectors are modelled within the Aglink-Cosimo framework. The links between non-renewable energy (fossil fuel) and biofuels are unidirectional; that is, the biofuels module considers the changes in gasoline and diesel price and demand, while the energy models do not take into consideration biofuel (ethanol and biodiesel) prices and are beyond the scope of the Aglink-Cosimo modelling framework. However, the link between the biofuels module and the agricultural model is bidirectional: changes in agricultural feedstock prices can lead to the changes in the production of biofuels and vice-versa.

This module includes the major food-based feedstocks – maize, wheat, soybean oil, rapeseed oil, palm oil – and non-food based feedstocks –, switchgrass and miscanthus, and used cooking oil and animal fats. Several other feedstocks are also included in the new templated biofuels modules of the Aglink-Cosimo model. Table 1 presents a detailed list.

Figure 1. Linkages between international biodiesel model and the international agricultural, livestock, dairy and sugar modelling system

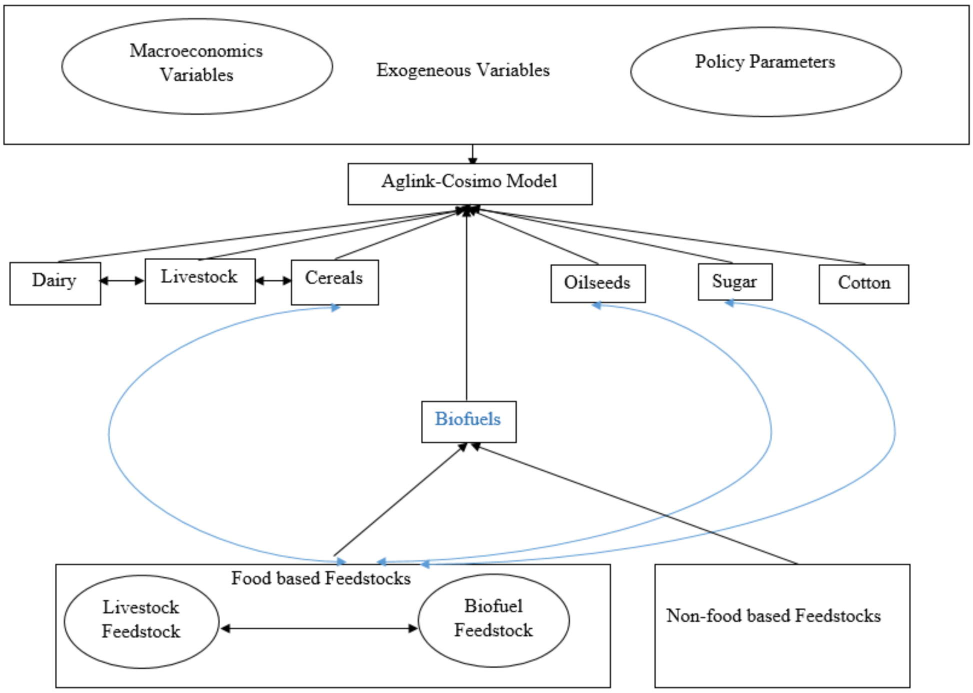


Figure 2. Linkage between energy and agricultural sectors via biofuels

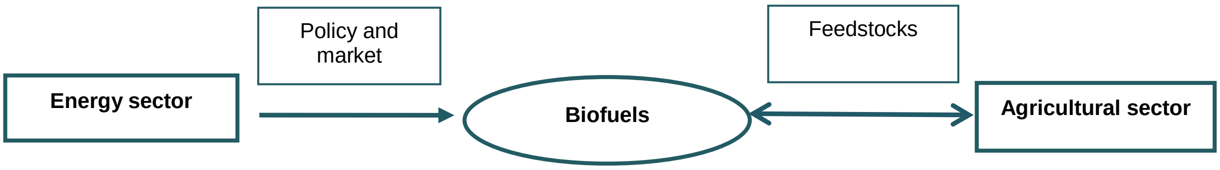


Table 1. Feedstock use in the production of two types of biofuels: Ethanol and biodiesel

Feedstock use	Acronyms	Biofuels	Products included
Maize	MA	Ethanol	—
Molasses	MOL	Ethanol	—
Other coarse grain	OCG	Ethanol	Barley, rye
Rice	RI	Ethanol	—
Root and tubers	RT	Ethanol	Cassava, potato
Wheat	WT	Ethanol	—
Sugar beet	SBE	Ethanol	—
Sugar cane	SCA	Ethanol	—
Jatropha	JA	Biodiesel	
Vegetable oil	VL	Biodiesel	Palm oil, rapeseed oil, soybean oil, sunflower oil, other vegetable Oil
Waste oils and fats	WLF	Biodiesel	Used cooking oil (uco) and animal fats
Agriculture residue	ARES	Ethanol / biodiesel	Wheat straw, bagasse, corn stover
Dedicated energy crops	ECR	Ethanol / biodiesel	Woody crops (short rotation crops: willow, poplar, eucalyptus), herbaceous crops (perennials: switchgrass, miscanthus)
Forestry residue	FRES	Ethanol / biodiesel	Wood chips, logging residues
Municipal solid waste	MSW	Ethanol / biodiesel	—
Other waste and residues	OTHW	Ethanol / biodiesel	Notably paper and pulp industry waste

3. DATA SOURCES

Data are obtained from many sources: industrial sources for ethanol and biodiesel production, use, imports, exports, stock volumes and prices; the US Department of Agriculture GAIN reports for the use of different types of feedstocks for production;; and the *Annual Outlook Report* of the International Energy Agency for the domestic volume of gasoline and diesel use. Macroeconomic variables, such as exchange rates and GDP, are based on the OECD's *Economic Outlook*, and population and crude oil prices on World Bank reports. Figures 3 and 4 show the price linkage between biofuels (ethanol and biodiesel), petroleum products (gasoline and diesel) and feedstocks (maize and vegetables). This is very important for baseline projections and policy-based scenario analysis.

Figure 3. Change in world ethanol price, world crude oil price, and world maize price, % change year-to-year

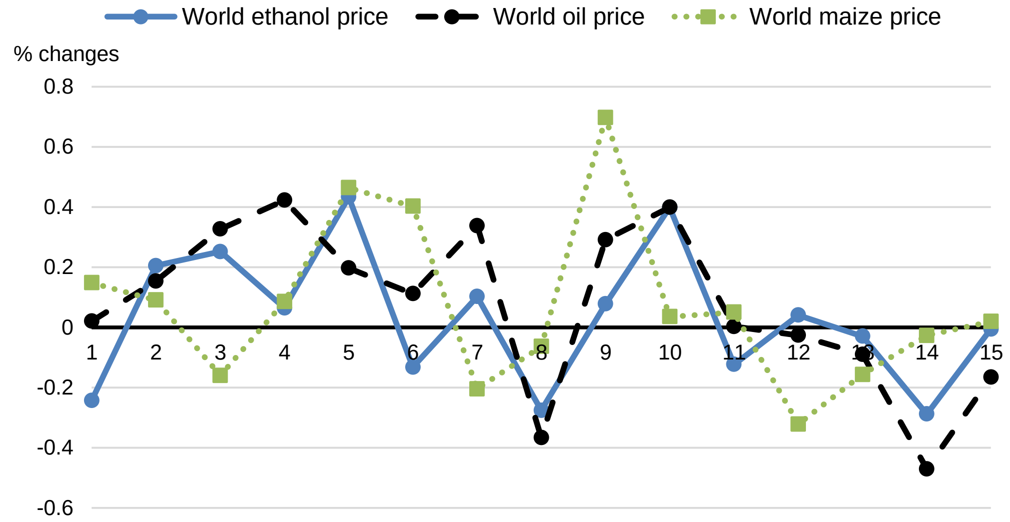
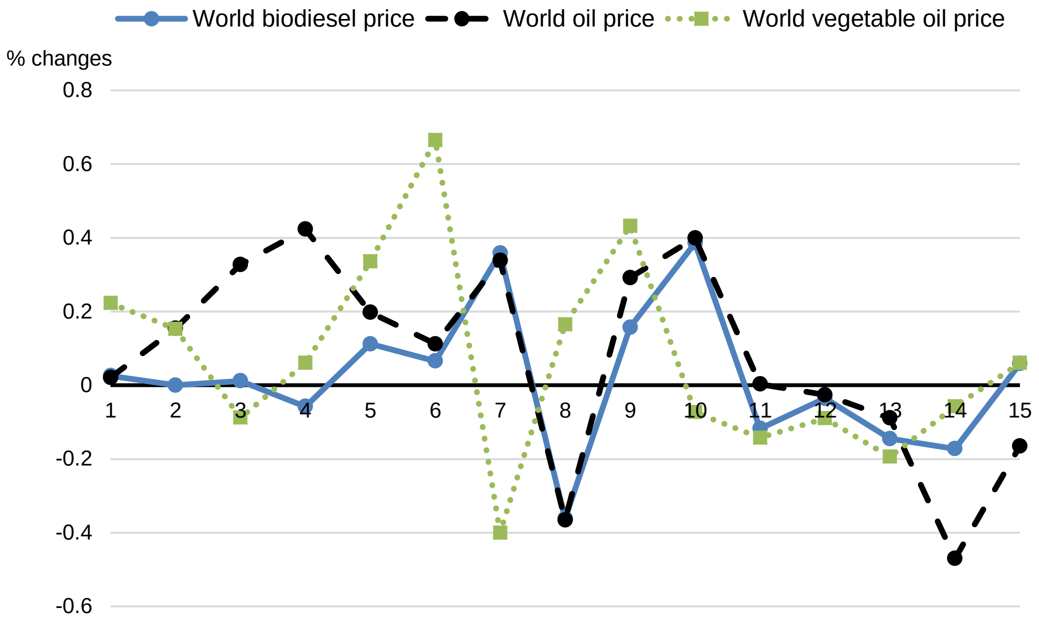


Figure 4. Change in world biodiesel price, world crude oil price, and world vegetable oil price, % change year-to-year

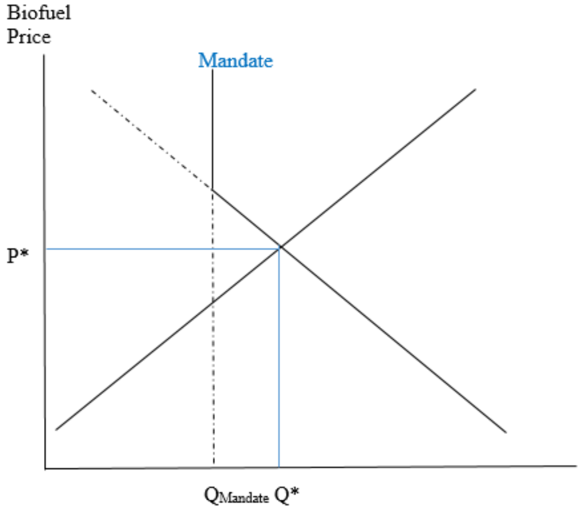


4. Policies

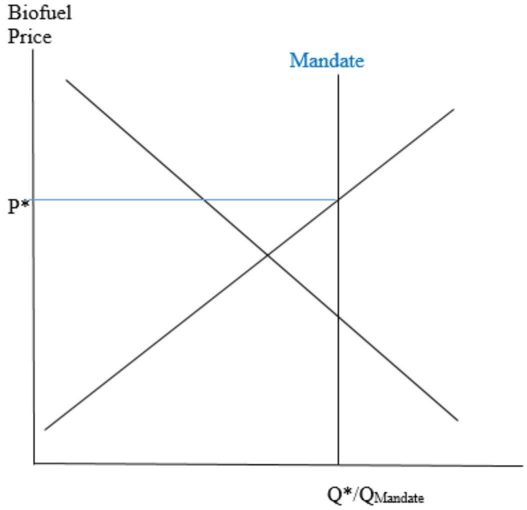
Mandates on the domestic use of ethanol or biodiesel play an important role in modelling the demand for biofuels within the biofuels module. Given that policies regulate biofuel demand, the link between biofuels and crude oil prices is relatively limited, except for the crude oil price which drives the total fuel use which further drives biofuels use (in percentage terms). However, the development of biofuels beyond the mandate levels depends on the comparative price ratio between biofuels and crude oil. When the price of crude oil falls, biofuels are less competitive resulting in lower market-driven demand and lower investments in the sector. Higher transportation biofuel use can partially compensate for this.

Domestic mandates for biofuels can be either binding or non-binding (Figures 5a and 5b) depending on country-specific use. The mandate is non-binding if the mandated level of biofuels use is below the market equilibrium (Figure 5a) and binding when the domestic mandate pushes biofuels use and production beyond the conventional market equilibrium (Figure 5b). In the case of binding mandate, the biofuels price is above the equilibrium price, while the non-binding mandate has no effect on the market equilibrium. Where the mandate is binding, this is considered a policy support to biofuels producers.

Figure 5 a. Non-binding biofuels use



5b. Binding biofuels use



Box 1. Endogenous gasoline and diesel equation

Country-specific endogenous domestic gasoline and diesel use are modelled in the biofuel module. The domestic fossil fuels are modelled as a function of own (gasoline and/ diesel price) and cross (ethanol and biodiesel) prices, income and vehicle fuel efficiencies (trend). A double log model is used in the estimation. The country-specific domestic gasoline use equation is modelled as follows:

$$\log GS_{c,t} = \alpha_0 + \alpha_1 * \log CP^{GS}_{c,t} + \alpha_2 * \log CP^{ET}_{c,t} + \alpha_3 * \log I_{c,t} + \alpha_4 * V_{c,t} + \varepsilon^{GS}_{c,t}$$

where, $GS_{c,t}$ is the per capita gasoline consumption in country c and year t, $CP^{GS}_{c,t}$ is the gasoline consumer price in country c and year t, $CP^{ET}_{c,t}$ is the ethanol consumer price in country c and year t, $I_{c,t}$ is the per capita GDP in country c year t, $V_{c,t}$ is the vehicle fuel efficiency in country c and year t, α_0, and α_1, α_2, α_3, α_4 are the corresponding intercepts and slope coefficients, and, $\varepsilon^{GS}_{c,t}$ is the corresponding error term. The country specific domestic gasoline use equation is model as below:

$$\log DE_{c,t} = \beta_0 + \beta_1 * \log CP^{DE}_{c,t} + \beta_2 * \log CP^{BD}_{c,t} + \beta_3 * \log I_{c,t} + \beta_4 * V_{c,t} + \varepsilon^{DE}_{c,t}$$

where, $DE_{c,t}$ is the per capita diesel consumption in country c in year t, $CP^{DE}_{c,t}$ is the diesel consumer price in country c and year t, $CP^{BD}_{c,t}$ is the biodiesel consumer price in country c and year t, $I_{c,t}$ is the per capita GDP in country c year t, $V_{c,t}$ is the vehicle fuel efficiency in country c and year t, β_0, and β_1, β_2, β_3, β_4 are the corresponding intercepts and slope coefficients, and, $\varepsilon^{GS}_{c,t}$ is the corresponding error term.

The parameters associated with the slope coefficients can be interpreted as own, and cross price elasticities and income elasticity, respectively.

5. Elasticities

Like other components of the Aglink-Cosimo model, the biofuels module include some elasticities assumptions. Unlike cereals, livestock, and dairy modules where the own- and cross-price and income elasticities in the demand equation play an important role in the projections, the elasticities in the biofuels module are not significantly relevant as the demand for ethanol and biodiesel is driven mainly by domestic mandate policies. However, when calculated in terms of percentages these domestic mandates can be interpreted as an increase or decrease in gasoline and diesel use which lead to an increase or decrease in overall ethanol and biodiesel use.

Therefore, the elasticities corresponding to the newly added country-specific gasoline and diesel use equations are important in simulating baseline projection and scenarios.

The own (gasoline and diesel) price and cross (ethanol and biodiesel) price and income elasticities associated with the country-specific domestic gasoline use are listed in Table 2 and Table 3. In the cases of Brazil (ethanol), United States (ethanol, and biodiesel), and the European Union (ethanol and biodiesel) all the elasticities come from the log-log model (previously mentioned), while for other countries the own (gasoline and diesel) price and income elasticities are also derived from the log-log model but exclude the cross (ethanol and biodiesel) price effect as ethanol is not available at the retail level. However, the cross-price elasticity summarised below are obtained from the estimates for gasoline demand, which includes both the own- and cross-price effects.

Table 2. Price and income elasticities corresponding to the country-specific gasoline demand equation

Country	Own-price elasticity	Cross-price elasticity	Income elasticity
Argentina	-0.34	-0.53	1.61
Australia	-0.01	-0.13	1.68
Brazil	-0.76	0.35	0.38
Canada	-0.04	-0.03	0.1
China	-0.12		1.156
European Union	-0.25	-0.04	0.51
Japan	-0.42	0.16	1.16
Korea	-0.08	-0.06	0.32
Mexico	-0.38	-0.07	0.33
New Zealand	-0.02	-0.04	1.12
Norway	-0.07	-0.02	1.2
Russian Federation	-0.1		0.29
Switzerland	-0.03		2.64
United States	-0.04	-0.03	0.88
Colombia	-0.01	-0.05	0.35
Chile	-0.31	0.52	0.53
India	-0.02		0.25
Indonesia	-0.02	-0.02	1.63
Malaysia	-0.15	-0.4	1.63
Paraguay	-0.11	0.12	1.54
Peru	-0.36	-0.33	1.15
Philippines	-0.25		0.75
Thailand	-0.41	0.12	0.52

Table 3. Price and income elasticities corresponding to the country-specific diesel demand equation

Country	Own-price elasticity	Cross-price elasticity	Income elasticity
Argentina	-0.24	0.02	1.15
Australia	-0.03	-0.02	0.37
Brazil	-0.09	0.02	1.06
Canada	-0.03	0.05	0.13
China	-0.13		1.15
European Union	-0.03	0.02	0.63
Japan	-0.2	-0.31	0.69
Korea	-0.07	0.267	0.44
Mexico	-0.41	-0.08	0.3
New Zealand	-0.04	0.12	0.83
Norway	-0.17	0.06	0.89
Russian Federation	-0.1	-0.001	0.29
Switzerland	-0.1		1.41
United States	-0.08	-0.003	0.7
Colombia	-0.04		1.36
Chile	-0.0083	0.33	2.94
India	-0.02	0.16	0.25
Indonesia	-0.02	0.07	1.63
Malaysia	-0.16	-0.24	1.58
Paraguay	-0.13	0.23	0.15
Philippines	-0.29		1.68
Thailand	-0.14	0.02	1.19

The assumed ethanol and biodiesel export and import demand elasticities in the biofuels module of the Aglink-Cosimo model are listed in Table 4.

Table 4. Country-specific ethanol and biodiesel export and import demand elasticities

Country	Commodity	Export demand elasticity	Import demand elasticity
Brazil	Ethanol	-4.99	6.7
European Union	Ethanol	-2	8
All countries except Brazil and EU	Ethanol	-4.99	8
All countries	Biodiesel	-2	5

6. MODEL

The biofuels module follows the same structure as the Aglink-Cosimo model and is linked to the other components of the model via the corresponding feedstock use links. On the supply side of the biofuel module, the feedstocks producer price index obtained from the other components of the Aglink-Cosimo model is used to derive the biofuels production costs. On the demand side, the biofuels demand is tied to the petroleum products demand and the price ratio between the biofuels (ethanol and biodiesel) price and the gasoline and diesel price that drive it. At equilibrium, the demand and supply of biofuels interact and solve the equilibrium price and quantity (Figure 6).

The major updates to the demand side of the biofuels module are shown in Figure 7. The inclusion of endogenous petroleum products is a new addition that increases the overall capabilities of the Aglink-Cosimo model to analyse biofuels and climate change-related scenarios. Figure 7 shows that in addition to the endogenous gasoline and diesel use, the inclusion of endogenous high blend ethanol and biodiesel domestic use has significantly increased the robustness of the biofuels module. The low blend biofuels domestic use is driven by policy as well as fuel additives, while high blend use is sensitive to the biofuels and petroleum products price ratios.

Figure 6. Schematic diagram of the biofuels module of the Aglink-Cosimo

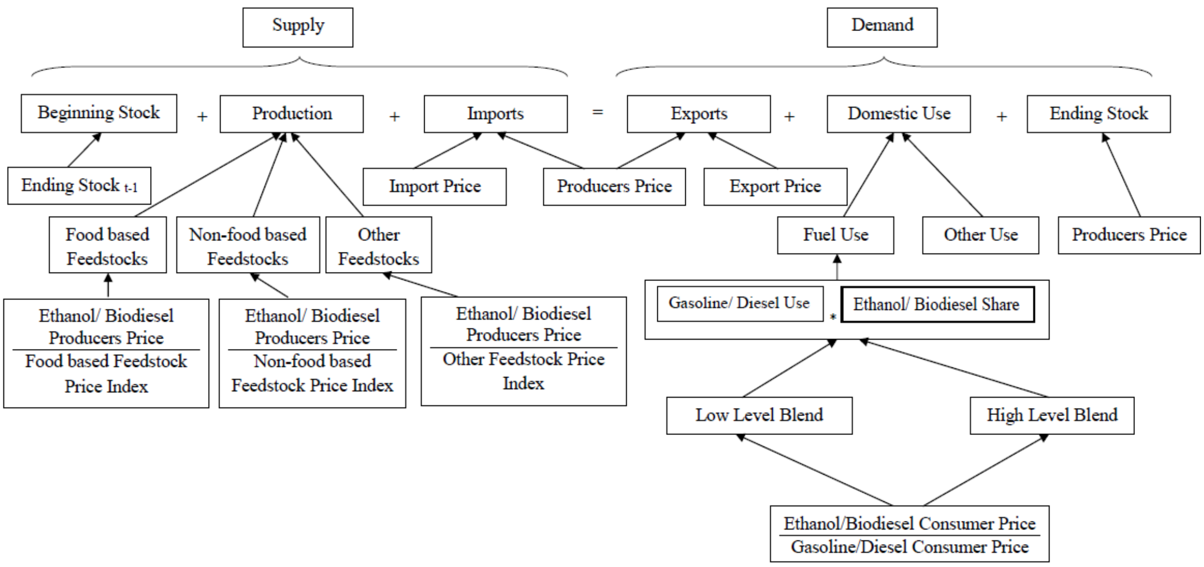
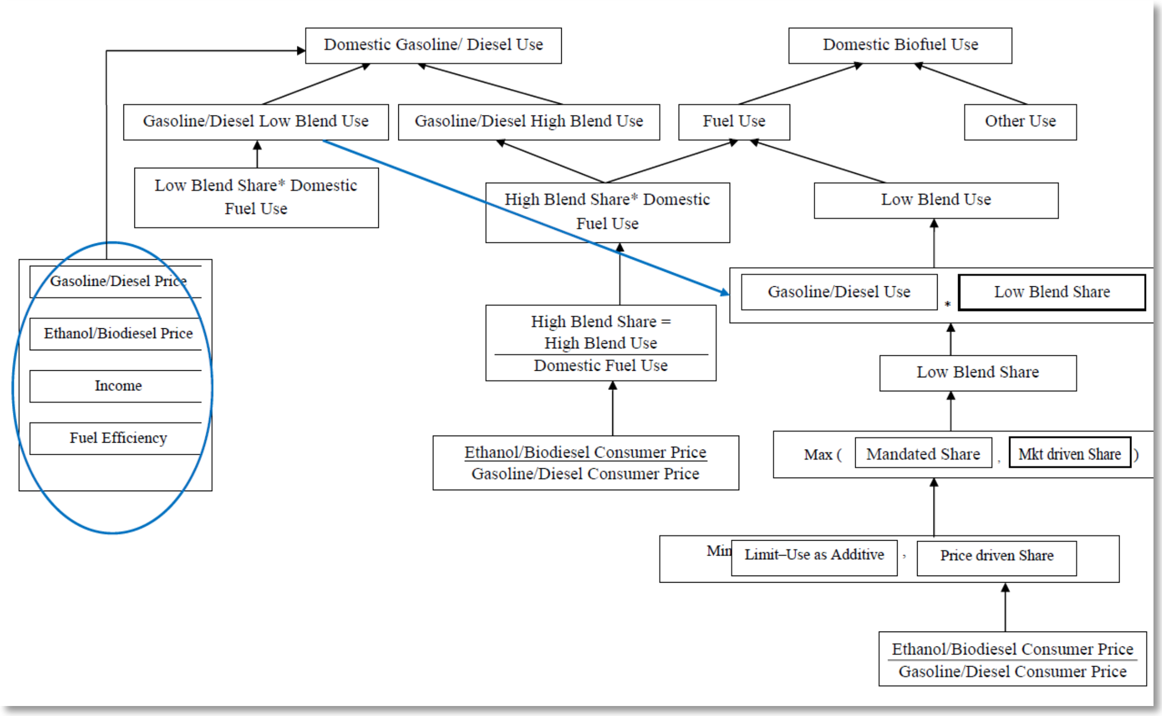


Figure 7. Flowchart of the high and low blend domestic biofuels use



6.1 Equilibrium condition

The biofuels module has its own market equilibrium for each country covered by the Aglink and Cosimo models. The two market equilibrium conditions that correspond to the specific ethanol and biodiesel markets are represented as follows:

$$ST^{ET}_{c,t-1} + QP^{ET}_{c,t} + IM^{ET}_{c,t} = QC^{ET}_{c,t} + EX^{ET}_{c,t} + ST^{ET}_{c,t} \quad (7)$$

where

$ST^{ET}_{c,t-1}$	=	the beginning stocks of ethanol in country c and year t
$QP^{ET}_{c,t}$	=	the production of ethanol in country c and year t
$IM^{ET}_{c,t}$	=	the import of ethanol in country c and year t
$QC^{ET}_{c,t}$	=	the domestic use of ethanol in country c and year t
$EX^{ET}_{c,t}$	=	the export of ethanol in country c and year t
$ST^{ET}_{c,t}$	=	the stock of ethanol in country c and year t.

$$ST^{BD}_{c,t-1} + QP^{BD}_{c,t} + IM^{BD}_{c,t} = QC^{BD}_{c,t} + EX^{BD}_{c,t} + ST^{BD}_{c,t} \quad (8)$$

where

$ST^{BD}_{c,t-1}$	=	the beginning stocks of biodiesel in country c and year t
$QP^{BD}_{c,t}$	=	the production of biodiesel in country c and year t
$IM^{BD}_{c,t}$	=	the import of biodiesel in country c and year t
$QC^{BD}_{c,t}$	=	the domestic use of biodiesel in country c and year t
$EX^{BD}_{c,t}$	=	the export of biodiesel in country c and year t
$ST^{BD}_{c,t}$	=	the export of biodiesel in country c and year t

Based on the above conditions the biofuels module determines country-specific ethanol and biodiesel producers price separately.

The equilibrium conditions that solve the biofuels module for world ethanol and biodiesel prices separately are as follows:

$$\sum_{c=1}^{n} EX^{ET}_{c,t} = \sum_{c=1}^{n} IM^{ET}_{c,t} \tag{9}$$

where

$EX^{ET}_{c,t}$ = the ethanol export in country c and year t

$IM^{ET}_{c,t}$ = the ethanol import in country c and year t

$$\sum_{c=1}^{n} EX^{BD}_{c,t} = \sum_{c=1}^{n} IM^{BD}_{c,t} \tag{10}$$

where

$EX^{BD}_{c,t}$ = the ethanol export in country c and year t

$IM^{BD}_{c,t}$ = the ethanol import in country c and year t

6.2. Biofuels price equation

The ethanol and biodiesel retail price is calculated based on the following identities:

$$CP^{ET}_{c,t} = PP^{ET}_{c,t} + TAX^{ET}_{c,t} + MAR^{ET}_{c,t} \tag{11}$$

where

$CP^{ET}_{c,t}$ = the ethanol consumer price in country c and year t

$PP^{ET}_{c,t}$ = the ethanol producer price in country c and year t

$TAX^{ET}_{c,t}$ = the tax imposed on ethanol price in country c and year t

$MAR^{ET}_{c,t}$ = the margin of ethanol sales that is the difference between the wholesale and retail prices.

$$CP^{BD}_{c,t} = PP^{BD}_{c,t} + TAX^{BD}_{c,t} + MAR^{BD}_{c,t} \tag{12}$$

where

$CP^{BD}_{c,t}$ = the biodiesel consumer price in country c and year t

$PP^{BD}_{c,t}$ = the biodiesel producer price in country c and year t

$TAX^{BD}_{c,t}$ = the tax imposed on biodiesel price in country c and year t

$MAR^{BD}_{c,t}$ = the margin of biodiesel sales that is the difference between the wholesale and retail prices.

The country-specific *ad valorem* tax consistent with the current policy is assumed over the projection period. Except for Brazil, the United States, and the European Union there is no retail market for biofuels. Therefore, in the absence of such a market, the existing gasoline and diesel tax is assumed as the ethanol and biodiesel tax.

Separate import and export prices for ethanol and biodiesel are calculated. The following equations are used for this purpose:

$$EP^{ET}_{c,t} = EP^{ET}_{w,t} * XR_{c,t} * EXA^{ET}_{c,t} \tag{13}$$

where

$EP^{ET}_{c,t}$ is the ethanol export price in country c and year t

$EP^{ET}_{w,t}$ is the world ethanol export price in year t,

$EXA^{ET}_{c,t}$ is the country-specific exported ethanol quality adjustment factor in country c and year t.

$$IP^{ET}_{c,t} = IP^{ET}_{w,t} * XR_{c,t} * IMA^{ET}_{c,t} \tag{14}$$

where

$IP^{ET}_{c,t}$ = the ethanol import price in country c and year t

$IP^{ET}_{w,t}$ = the world ethanol import price in year t

$IMA^{ET}_{c,t}$ = the country-specific imported ethanol quality adjustment factor in country c and year t.

And at equilibrium:

$$EP^{ET}_{w,t} = IP^{ET}_{w,t} \tag{15}$$

$$EP^{BD}_{c,t} = EPBDw_{,t} * XR_{c,t} * EXA^{BD}_{c,t} \tag{16}$$

where

$EP^{BD}_{c,t}$ = the biodiesel export price in country c and year t

$EP^{BD}_{w,t}$ = the world biodiesel export price in year t,

$EXA^{BD}_{c,t}$ = the country-specific exported biodiesel quality adjustment factor in country c and year t.

$$IP^{BD}_{c,t} = IP^{BD}_{w,t} * XR_{c,t} * IMA^{BD}_{c,t} \tag{17}$$

where

$IP^{BD}_{c,t}$ = the biodiesel import price in country c and year t

$IP^{BD}_{w,t}$ = the world biodiesel import price in year t

$IMA^{BD}_{c,t}$ = the country-specific imported biodiesel quality adjustment factor in country c and year t.

And at equilibrium:

$$EP^{BD}_{w,t} = IP^{BD}_{w,t}. \tag{18}$$

6.3 Domestic use equation

The biofuels module models only the fuel use of ethanol and biofuels while other uses of ethanol and biodiesel is exogenously assumed over the projection periods (Figure 7). The equations below represent total ethanol and biodiesel domestic consumption:

$$QC^{ET}_{c,t} = FL^{ET}_{c,t} + OU^{ET}_{c,t} \tag{19}$$

where

$QC^{ET}_{c,t}$ = the domestic use of ethanol in country c and year t

$FL^{ET}_{c,t}$ = the domestic fuel use of ethanol in country c and year t

$OU^{ET}_{c,t}$ = the domestic other use of ethanol in country c and year t

$$QC^{BD}_{c,t} = FL^{BD}_{c,t} + OU^{BD}_{c,t} \tag{20}$$

where

$QC^{BD}_{c,t}$ = the domestic use of biodiesel in country c and year t

$FL^{BD}_{c,t}$ = the domestic fuel use of biodiesel in country c in year t, $OU^{BD}_{c,t}$ is the domestic other use of biodiesel in country c and year t.

Further, domestic fuel ethanol and biodiesel use are modelled within the biofuels module (Figure 7) using the following equations:

$$FL^{ET}_{c,t} = LB^{ET}_{c,t} + HB^{ET}_{c,t} \tag{21}$$

where

$LB^{ET}_{c,t}$ = the domestic use of low blend fuel ethanol use in country c and year t

$HB^{ET}_{c,t}$ = the domestic use of high blend fuel ethanol use in country c and year t

With exception of Brazil, the majority of ethanol use is in the form of low blend which is driven by domestic policy mandates. However, there are other nested fuel uses of ethanol which are counted with low blend ethanol use, including fuel additive use, and market driven low blend use which are represented as follows:

$$LB^{ET}_{c,t} = LS^{ET}_{c,t} * GS_{c,t} / EE^{ET} \tag{22}$$

where

$LS^{ET}_{c,t}$ = the total low blend domestic ethanol use in terms of percentage in country c in year t,

$GS_{c,t}$ = the total domestic gasoline use in country c and year t

EE^{ET} = the energy equivalent of ethanol and gasoline, which is assumed to be 0.67.

It includes domestic ethanol use as fuel additive and policy-driven higher mandates which are capped at the blend wall limits (Figure 7). However, in the case of Cosimo (developing) countries and Argentina where mandates are not achievable, the mandates are adjusted as:

$$LS^{ET}_{c,t} = \max(MA^{ET}_{c,t}, QS^{ET}_{c,t}) \tag{23}$$

where

$MA^{ET}_{c,t}$ = the domestic adjusted energy equivalent ethanol mandate obligation in terms of percentage in country c and year t

$QS^{ET}_{c,t}$ = the total domestic variable non-mandate driven low blend ethanol use in terms of percentage in country c and year t

$$MA^{ET}_{c,t} = EE^{ET} * AJ^{ET}_{c,t} / (1-(1-EE^{ET}) * AJ^{ET}_{c,t}) \quad (24)$$

where

$AJ^{ET}_{c,t}$ = the domestic ethanol adjusted mandates in terms of percentage in country c and year t

$$AV^{ET}_{c,t} = SV^{ET}_{c,t} * OM^{ET}_{c,t} \quad (25)$$

where

$SV^{ET}_{c,t}$ = the share of adjustment of the actual mandate in country c and year t

$OM^{ET}_{c,t}$ = the domestic ethanol actual mandates in terms of percentage in country c and year t

$$QS^{ET}_{c,t} = AD^{ET}_{c,t} + MR^{ET}_{c,t} \quad (26)$$

where

$AD^{ET}_{c,t}$ = the domestic fuel additive use of ethanol in terms of percentage in country c and year t

$MR^{ET}_{c,t}$ = the domestic low blend ethanol use in terms of percentage in country c and year t

$$MR^{ET}_{c,t} = \min((MN^{ET}_{c,t} - AD^{ET}_{c,t}), MK^{ET}_{c,t}) \quad (27)$$

where

$MN^{ET}_{c,t}$ = the domestic market capacity limit (blend-wall) in terms of percentage in country c and year t

$MK^{ET}_{c,t}$ = the domestic market driven ethanol use in terms of percentage in country c and year t

$$MK^{ET}_{c,t} = \frac{1}{1+\exp(4*\kappa*(CP^{ET}_{c,t}/CP^{GS}_{c,t} - EE^{ET})} . \quad (28)$$

The high blend ethanol use is modelled as follow:

$$HB^{ET}_{c,t} = HS^{ET}_{c,t} * GS_{c,t} / EE^{ET} \quad (29)$$

where

$HS^{ET}_{c,t}$ = the high blend ethanol use in terms of percentage in country c and year t

$$HS^{ET}_{c,t} = \frac{1}{1+\exp(4*\kappa*(CP^{ET}_{c,t}/CP^{GS}_{c,t} - EE^{ET})}$$

And, total domestic biodiesel use is modelled using the following equations:

$$FL^{BD}_{c,t} = LB^{BD}_{c,t} + HB^{BD}_{c,t} \quad (30)$$

where

$LB^{BD}_{c,t}$ = the domestic use of low blend fuel biodiesel use in country c and year t,

$HB^{BD}_{c,t}$ = the domestic use of high blend fuel biodiesel use in country c and year t.

$$LB^{BD}_{c,t} = MN^{BD}_{c,t} * DE_{c,t} / EE^{BD} \quad (31)$$

where

$MN^{BD}_{c,t}$ = the domestic biodiesel use mandate in terms of percentage in country c and year t

$DE_{c,t}$ = the total domestic diesel use in country c and year t

EE^{BD} = the energy equivalent between biodiesel and diesel, which is assumed to be 0.92.

It includes domestic biodiesel use as discretionary blend and policy-driven higher mandates which are capped at the blend wall limits (Figure 7). However, in case of developing countries where mandates are not achievable, the mandates are adjusted as:

$$LS^{BD}_{c,t} = \max(MA^{BD}_{c,t}, QS^{BD}_{c,t}) \quad (32)$$

where

$MA^{BD}_{c,t}$ = the domestic adjusted energy equivalent biodiesel mandate obligation in terms of percentage in country c and year t

$QS^{BD}_{c,t}$ = the total domestic variable non-mandate driven low blend biodiesel use in terms of percentage in country c and year t

$$MA^{BD}_{c,t} = EE^{BD} * AJ^{BD}_{c,t} / (1-(1- EE^{BD}) * AJ^{BD}_{c,t}) \quad (33)$$

where

$AJ^{BD}_{c,t}$ = the domestic biodiesel adjusted mandates in terms of percentage in country c and year t

$$AV^{BD}_{c,t} = SV^{BD}_{c,t} * OM^{BD}_{c,t} \quad (34)$$

where

$SV^{BD}_{c,t}$ = the share of adjustment of the actual mandate in country c and year t

$OM^{BD}_{c,t}$ = the domestic biodiesel actual mandates in terms of percentage in country c and year t

$$QS^{BD}_{c,t} = AD^{BD}_{c,t} + MR^{BD}_{c,t} \quad (35)$$

where

$AD^{BD}_{c,t}$ = the domestic fuel additive use of biodiesel in terms of percentage in country c and year t

$MR^{BD}_{c,t}$ = the domestic low blend biodiesel use in terms of percentage in country c and year t

$$MR^{BD}_{c,t} = \min((MN^{BD}_{c,t} – AD^{BD}_{c,t}), MK^{BD}_{c,t}) \quad (36)$$

where

$MN^{BD}_{c,t}$ = the domestic market capacity limit (blend-wall) in terms of percentage in country c and year t

$MK^{BD}{}_{c,t}$ = the domestic market driven biodiesel use in terms of percentage in country c and year t

$$MK^{BD}_{c,t} = \frac{1}{1 + \exp(4 * \kappa * (CP^{ET}_{c,t} / CP^{GS}_{c,t} - EE^{ET})} . \qquad (37)$$

The high blend biodiesel use is modelled as follow:

$$HB^{BD}{}_{c,t} = HS^{BD}{}_{c,t} * GS_{c,t} / EE^{BD} \qquad (38)$$

where

$HS^{BD}{}_{c,t}$ = the high blend biodiesel use in terms of percentage in country c and year t.

$$HS^{BD}_{c,t} = \frac{1}{(1 + \exp(4 * \kappa * (CP^{BD}_{c,t} / CP^{DE}_{c,t} - EE^{BD})} . \qquad (39)$$

The $HS^{ET}{}_{c,t}$ and $HS^{BD}{}_{c,t}$ equations are the new addition to the biofuels module. It allows the Aglink-Cosimo model to capture high blend ethanol and biodiesel use in simulations of climate change mitigation scenarios. However, in baseline cases the high blend ethanol and biodiesel share is zero with the exception of the Brazilian ethanol market where the consumer can substitute between ethanol and gasoline.

As mentioned above, the ethanol and biodiesel share is modelled in terms of percentage of country-specific total domestic gasoline and diesel use. The following equations show the links between renewable (ethanol and biodiesel) and non-renewable fuel (gasoline and diesel):

$$GS_{c,t} = LB^{GS}{}_{c,t} + HB^{GS}{}_{c,t} \qquad (40)$$

where

$GS_{c,t}$ = the total domestic gasoline use in country c and year t.

$LB^{GS}{}_{c,t}$ = the low blend gasoline use in country c and year t.

$HB^{GS}{}_{c,t}$ = the high blend gasoline use in country c and year t.

$$HB^{GS}{}_{c,t} = HB^{ET}{}_{c,t} * EE^{ET} \qquad (38)$$

$$LB^{GS}{}_{c,t} = FL^{GS}{}_{c,t} - HB^{GS}{}_{c} \qquad (39)$$

Basically, at the energy equivalent, high blend gasoline use ($HB^{GS}{}_{c,t}$) equals high blend ethanol use ($HB^{ET}{}_{c,t}$) in country c in year t.

$$DE_{c,t} = HB^{DE}{}_{c,t} + LB^{DE}{}_{c,t} \qquad (40)$$

where

$DE_{c,t}$ = the total domestic diesel use in country c and year t

$LB^{DE}{}_{c,t}$ = the low blend diesel use in country c and year t

$HB^{DE}{}_{c,t}$ = the high blend diesel use in country c and year t

$$HB^{BD}{}_{c,t} = HB^{BD}{}_{c,t} * EE^{BD} \qquad (41)$$

$$LB^{GS}{}_{c,t} = FL^{DE}{}_{c,t} - HB^{DE}{}_{c} \qquad (42)$$

Similarly, at the energy equivalent, high blend diesel use ($HB^{BD}{}_{c,t}$) equals high blend biodiesel use ($HB^{BD}{}_{c,t}$) in country c in year t.

6.4 Production equation

Biofuels are produced from various feedstocks and this differs from country to country. Table 7 summarises the modelled country specific feedstocks used for biofuels production within the biofuels module.

Table 7. Country specific feedstock use modelled within the biofuels module in the production of two types of biofuels: Ethanol and biodiesel

Feedstock use	Acronyms	Biofuels	Countries modelled
Maize	MA	Ethanol	ARG, CAN, CHN, EUN, MEX, RUS, USA, NZL
Molasses	MOL	Ethanol	AUS, JPN, BRA, IND, IDN, THA, PHL
Other coarse grain	OCG	Ethanol	AUS, CHN, EUN, RUS, USA
Rice	RI	Ethanol	JPN, KOR
Root and tubers	RT	Ethanol	CHN, THA
Wheat	WT	Ethanol	AUS, CAN, CHN, EUN,NOR, RUS, JPN
Sugar beet	SBE	Ethanol	EUN
Sugar cane	SCA	Ethanol	ARG,BRA
Dedicated energy crops	ECR	Ethanol	USA
Vegetable oil	VL	Biodiesel	ARG, BRA, CAN, EUN, KOR, NOR, USA
Soybean oil	SL	Biodiesel	ARG, BRA, CAN, EUN, KOR, USA, PRY
Rapeseed oil	RL	Biodiesel	CAN, EUN, NOR
Palm oil	PL	Biodiesel	EUN, KOR, IDN, MYS, COL, THA, PER
Sunflower oil	SFL	Biodiesel	EUN

The following equations are used separately to establish the link between ethanol and biodiesel, and the corresponding feedstocks market:

$$QP^{ET}_{c,t} = \sum_{i=1}^{n} FS^{ET}_{i,c,t} \tag{43}$$

where

$QP^{ET}{}_{c,t}$ = the total quantity of ethanol produced in country c and year t

$FS^{ET}{}_{i,c,t}$ = the feedstock i used in the production of ethanol in country c and year t. 9 (n=9) different types of feedstocks used for ethanol production are included in the biofuels module and it varies across the countries (Table 7).

$$QP^{BD}_{c,t} = \sum_{i=1}^{m} FS^{BD}_{i,c,t} \tag{44}$$

where

$QP^{BD}{}_{c,t}$ = the total quantity of biodiesel produced in country c and year t

$FS^{BD}{}_{i,c,t}$ = the feedstock i used in the production of biodiesel in country c and year t.

Five (m=5) different types of feedstocks are used for biodiesel production within the biofuels module (Table 7).

Each feedstocks use in the production of ethanol and biodiesel is modelled separately, using the prescribed equations:

$$logFS^{ET}_{i,c,t} = v_0 + v_1*logRM^{ET}_{i,c,t} + v_2* logRM^{ET}_{i,c,t-1} + v_3* logRM^{ET}_{i,c,t-2} + v_4* logRM^{ET}_{i,c,t-3} + v_5*logFS^{ET}_{i,c,t-1} + \varepsilon^{ET}_{FS} \quad (45)$$

where

$RM^{ET}_{i,c,t}$ = the profit derived from utilizing feedstock i for the production of ethanol in country c and year t.

The $RM^{ET}_{i,c,t}$ is derived based on the following identity:

$$RM^{ET}_{i,c,t} = \frac{PP^{ET}_{c,t} + DP^{ET}_{i,c,t} + VL^{ET}_{i,c,t}}{PI^{ET}_{i,c,t}} \quad (46)$$

where

$PP^{ET}_{c,t}$ = the ethanol producer price in country c year t

$DP^{ET}_{i,c,t}$ = the direct government support for production of ethanol tied with the use of feedstock i in country c and year t

$VL^{ET}_{i,c,t}$ = the value of by-products derived from the use of feedstock i in ethanol production in country c and year t

$PI^{ET}_{i,c,t}$ = the production cost index associated with the use of feedstock i in the production of ethanol in country c and year t

ε^{ET}_{FS} = the corresponding error term.

The following equation is used to derive the production cost index of ethanol for each feedstock use:

$$PI^{ET}_{i,c,t} = SH^{ET}_{i,c,t} *PP^{ET}_{i,c,t-1} + EN^{ET}_{c,t}*OP_{c,t}*ER_{c,t} + CO^{ET}_{i,c,t}*GD_{c,t} \quad (47)$$

where

$SH^{ET}_{i,c,t}$ = the share of feedstock i in the cost index in the production of ethanol in country c and year t

$PP^{ET}_{i,c,t}$ = the producers price index of feedstock i in the production of ethanol in country c and year t in real term

$EN^{ET}_{c,t}$ = the energy share in the cost index in the production of ethanol in country c and year t

$OP_{c,t}$ = the crude oil price index in country c and year t in real term

$ER_{c,t}$ = the exchange rate in country c and year t in real term

$CO^{ET}_{i,c,t}$ = the share of co-products corresponding to the use of feedstock i in the cost index in the production of ethanol in country c and year t

$GD_{c,t}$ = the GDP deflator in real term in country c and year t.

The above equations serve as the link between the ethanol and agricultural markets for each country specific feedstocks (agricultural) market specified in Table 7.

$$logFS^{BD}_{i,c,t} = v_6 + v_7{*}logRM^{BD}_{i,c,t} + v_8{*}\ logRM^{BD}_{i,c,t-1} + v_9{*}\ logRM^{BD}_{i,c,t-2} + v_{10}{*}\ logRM^{BD}_{i,c,t-3} + v_{11}{*}logFS^{ET}_{i,c,t-1} + \varepsilon^{BF}_{FS} \quad (48)$$

where

$RM^{BD}_{i,c,t}$ = the profit derived from utilising feedstock i for the production of biodiesel in country c and year t

$$RM^{BD}_{i,c,t} = \frac{PP^{BD}_{c,t} + DP^{BD}_{i,c,t} + VL^{BD}_{i,c,t}}{PI^{BD}_{i,c,t}} \quad (49)$$

where

$PP^{BD}_{c,t}$ = the biodiesel producer price in country c and year t

$DP^{BD}_{i,c,t}$ = the direct government support for production of biodiesel tied with the use of feedstock i in country c and year t

$VL^{BD}_{i,c,t}$ = the value of by-products derived from the use of feedstock i in biodiesel production in country c and year t

$PI^{BD}_{i,c,t}$ = production cost index associated with the use of feedstock i in the production of biodiesel in country c and year t

ε^{BF}_{FS} = the corresponding error term.

The following equation is used to derive the production cost index of ethanol for each feedstock use:

$$PI^{BD}_{i,c,t} = SH^{BD}_{i,c,t}{*}PP^{BD}_{i,c,t-1} + EN^{BD}_{c,t}{*}OP_{c,t}{*}ER_{c,t} + CO^{BD}_{i,c,t}{*}GD_{c,t} \quad (50)$$

where

$SH^{BD}_{i,c,t}$ = the share of feedstock i in the cost index in the production of biodiesel in country c and year t,

$PP^{BD}_{i,c,t}$ = the producers price index of feedstock i in the production of biodiesel in country c and year t in real term

$EN^{BD}_{c,t}$ = the energy share in the cost index in the production of biodiesel in country c and year t

$OP_{c,t}$ = the crude oil price index in country c and year t in real term

$ER_{c,t}$ = the exchange rate in country c and year t in real term

$CO^{BD}_{i,c,t}$ = the share of coproducts corresponding to the use of feedstock i in the cost index in the production of biodiesel in country c and year t,

$GD_{c,t}$ = the GDP deflator in real term in country c and year t.

The above equations serve as the link between the biodiesel and agricultural markets for each country specific feedstocks (agricultural) market specified in Table 7.

6.5. Trade equation

The trade component of the biofuels module is consistent with the other components of the Aglink-Cosimo model. The country-specific export and import of ethanol and biodiesel are modelled separately. Each equation representing the export and import is shown below:

$$logEX^{ET}_{c,t} = \lambda_1 + \lambda_2 * \log(PP^{ET}_{c,t} / (EP^{ET}_{c,t} * (1 - EX^{ETT}_{c,t}))) + \varepsilon^{ET}_{EX} \quad (51)$$

where

$EX^{ET}_{c,t}$ = the export of ethanol in country c and year t

$PP^{ET}_{c,t}$ = the ethanol producer price in country c and year t

$EP^{ET}_{c,t}$ = the ethanol export price in country c and year t

$EX^{ETT}_{c,t}$ = the ethanol export tax in country c and year t

λ_1, λ_2 = the intercepts and slope coefficients

ε^{ET}_{EX} = the corresponding error term.

$$logIM^{ET}_{c,t} = \lambda_3 + \lambda_4 * (\log PP^{ET}_{c,t} / (IP^{ET}_{c,t} * (1 - IM^{ETT}_{c,t}))) + \varepsilon^{ET}_{IM} \quad (47)$$

where

$IM^{ET}_{c,t}$ = the import of ethanol in country c and year t

$PP^{ET}_{c,t}$ = is the ethanol producer price in country c and year t

$IP^{ET}_{c,t}$ = is the ethanol import price in country c and year t

$IM^{ETT}_{c,t}$ = is the ethanol import tax in country c and year t

λ_3, λ_4 = the intercepts and slope coefficients

ε^{ET}_{IM} = the corresponding error term.

$$logEX^{BD}_{c,t} = \lambda_5 + \lambda_6 * (\log PP^{BD}_{c,t} / (EP^{BD}_{c,t} * (1 - EX^{BDT}_{c,t}))) + \varepsilon^{BD}_{EX} \quad (52)$$

where

$EX^{BD}_{c,t}$ = the export of biodiesel in country c and year t

$PP^{BD}_{c,t}$ = the biodiesel producer price in country c and year t

$EP^{BD}_{c,t}$ = the biodiesel export price in country c and year t

$EX^{BDT}_{c,t}$ = the biodiesel export tax in country c and year t

λ_5, λ_6 = the intercepts and slope coefficients

ε^{BD}_{EX} = the corresponding error term.

$$logIM^{BD}_{c,t} = \lambda_7 + \lambda_8 * (\log PP^{BD}_{c,t} / (IP^{BD}_{c,t} * (1 - IM^{BDT}_{c,t}))) + \varepsilon^{BD}_{IM} \quad (53)$$

where

$IM^{BD}_{c,t}$ = the import of biodiesel in country c and year t

$PP^{BD}_{c,t}$ = the biodiesel producer price in country c and year t

$IP^{ET}_{c,t}$ = the biodiesel import price in country c and year t

$IM^{BDT}_{c,t}$ = the biodiesel import tax in country c and year t

λ_7, λ_8 = the intercepts and slope coefficients

$\varepsilon^{BD}{}_{IM}$ = the corresponding error term.

6.6. Stocks equation

Unlike cereals, biofuels stock are not crucial in terms of projecting into the future. The biofuels module uses the following equation for the ethanol stock:

$$\log ST^{ET}{}_{c,t} = \kappa_1 + \kappa_2 * (\log PP^{ET}{}_{c,t} / ((PP^{ET}{}_{c,t-1} + PP^{ET}{}_{c,t-2} + PP^{ET}{}_{c,t-3})/3) + \varepsilon^{ET}{}_{ST} \quad (54)$$

where

$ST^{ET}{}_{c,t}$ = the stock of ethanol in country c and year t

$PP^{ET}{}_{c,t}$ = the ethanol producer price in country c and year t

$\varepsilon^{ET}{}_{ST}$ = the corresponding error term.

7. Conclusion

This documentation provides details on the equations, variables, and biofuels module properties. The 2017 updates enable this module to simulate several policy scenarios, including climate change mitigation scenarios. The inclusion of high blend biofuels use and diverse spectrum of food- and non-food-based feedstocks make this updated biofuels module a valuable tool.

In the absence of a direct linkage between the petroleum and the biofuels modules, the inclusion of endogenous non-renewable fuel equations along with the high blend ethanol and biodiesel components make it possible to simulate policies under different sets of macroeconomic variables – including a wide range of crude oil prices – and to trace these to the world agricultural market via biofuels.

AGLINK-COSIMO Biofuels Module documentation

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