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Documentation of the European Comission's EU module of the Aglink-Cosimo modelling system

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with contributions of

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Abstract

This report documents the EU module of Aglink-Cosimo model. Aglink-Cosimo is a recursive-dynamic, partial equilibrium, supply demand model of world agriculture developed by the OECD and FAO Secretariats. The model is used to simulate development of annual supply, demand and prices for the main agricultural commodities produced, consumed and traded worldwide. Aglink-Cosimo covers 44 individual countries and 12 regions, and 40 commodities clearing markets at the world level.
At the EU level, the Aglink-Cosimo model is used to produce the "Prospects for Agricultural Markets and Income in the EU". This is a yearly exercise that provides a detailed overview of EU agricultural markets with a 10 year time horizon. It incorporates information from policy makers and market experts in the European Commission, stakeholders, researchers and modellers. The EU Outlook intends to provide a broad consensus about the evolution of European Agriculture in the medium-term. It serves as reference timeline for counterfactual policy analysis and market analysis done in numerous research sites in Europe.
The report includes a detailed presentation and discussion of the structure and specific features of the model, along with the theoretical underpinnings. It also documents the process of calibration such as to obtain a medium-term baseline and different efforts towards the validation of results. Nonetheless, different applications in the area of uncertainty analysis and the use of partial stochastics are also included.

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Executive summary

This report documents the EU module of the Aglink-Cosimo model. Aglink-Cosimo is a recursive-dynamic, partial equilibrium, multi-commodity market model of world agriculture developed by the Organisation for Economic Cooperation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO) Secretariats in collaboration with some OECD member countries. The model is used to simulate the development of annual supply, demand and prices for the main agricultural commodities produced, consumed and traded worldwide. Aglink-Cosimo covers 44 individual countries and 12 regions, and 40 commodities clearing markets at the world level.

At the EU level, the Aglink-Cosimo model is used to produce the report Prospects for Agricultural Markets and Income in the EU, also known as the EU Outlook. This is a yearly exercise that provides a detailed overview of EU agricultural markets over a 10-year time horizon. It incorporates information from policy makers and market experts in the European Commission, as well as from stakeholders, researchers and modellers. The aim of the EU Outlook is to provide a broad consensus on the evolution of European agriculture in the medium term. It serves as a reference timeline for counterfactual policy and market analysis undertaken at numerous research sites in Europe.

This report includes a detailed presentation and discussion of the structure and specific features of the model, along with its theoretical underpinnings. It also documents the process of calibration used to obtain a medium-term baseline and the various steps taken to validate the results. Different applications in the area of uncertainty analysis and the use of partial stochastic analysis are also included.

Keywords: partial equilibrium model, recursive-dynamic, trade, multi-commodity markets, agriculture, global model, baseline, medium-term outlook.

Contents

Preface: the history of the Aglink-Cosimo model

This great adventure started 25 years ago and was undertaken initially to improve the process of forecasting the development of agricultural markets by the Organisation for Economic Cooperation and Development (OECD). Before the creation of Aglink, this exercise at the OECD was based on a questionnaire completed annually by OECD member states and containing market projections for the next five years. This approach had some limitations, such as the lack of a world market and inconsistencies in the numbers resulting from different processes carried out by the member states' agencies. The best example of this inconsistency was the beef market in the Pacific region, with experts in countries exporting beef to Japan predicting that beef exports would be three times higher than Japanese experts' predictions of beef imports. The OECD was also convinced that improving the outlook process had to include the capacity to produce scenarios. Only a dynamic partial equilibrium model could meet these requirements.

The OECD did not wish to embark on an onerous modelling programme, and for that reason it decided to use as much as possible the data and elasticities available in the existing models developed by the national agencies. Using the same information also had the advantage of avoiding criticism about model parameters. Between 1990 and 1992, the first version of Aglink was built. It contained seven geographic components (Canada, USA, Australia, New Zealand, EU-12, Japan and the rest of the world) and the following products: wheat, coarse grains, oilseeds, protein meals, vegetable oils, beef and veal, pork, sheep meat, poultry, eggs, milk, fresh dairy products, butter, cheese and skimmed milk powder.

From 1992 to 1995, Aglink was gradually incorporated into the outlook process. The OECD did not want to replace the medium-term questionnaire with model results but, rather, wanted to use them in a complementary way. The OECD wanted to keep all the useful information contained in these questionnaires while at the same time ensuring market consistency throughout the model. Calibrating the country components to the member country forecasts for all model variables, including world reference prices, was the method adopted as the first step towards achieving this objective. In the second step, the consistent macroeconomic forecast produced by the economics department of the OECD was introduced and the Aglink model was used to arrive at global market equilibrium.

From 1995 to 2005, Aglink was used to produce the outlook (which became an annual exercise with a 10-year time horizon) and many alternative scenarios. The model grew in size as new products (rice, whole milk powder, casein, palm oil) and country modules (China, Korea, Argentina, Mexico, Brazil and Russia) were incorporated. The addition of these new countries reduced the size of the rest of the world aggregate. During the same period, the EU component increased from 12 to 15 Member States. Moreover, following the expansion of the EU, an additional component of new member countries was built, initially containing 10 countries on the supply side. However, on the demand side, the interaction with world markets was done through the EU-25 aggregate.

In 2005, the Cosimo model, developed and maintained by the Food and Agriculture Organization of the United Nations (FAO), was integrated into the Aglink system. This allowed the disaggregation of the rest of the world aggregate into more than 35 new country components. It also brought the FAO's market expertise to the outlook process, allowing a much better understanding of world markets. At that time, the sugar market was still subject to distortions created by government policies. As a consequence, a satellite model of the sweetener markets (i.e. sugar, high-fructose corn syrup and molasses) was built, in order to analyse the consequences of simultaneous reforms.

In 2007, a major structural change affected the agricultural markets, namely the explosion in the production of ethanol and biodiesel, partly stimulated by complex government policies. The OECD reacted promptly by building a biofuel module and a satellite module for sweeteners, because of the strong interactions between the ethanol, sugar and molasses markets. This structural change modified the emphasis of the model and the outlook from a policy reform focus to a food security focus. In addition, and in order to have a more complete picture of food security, a fish market satellite component was built and incorporated into the outlook process in 2012.

Following so many additions, the OECD and FAO decided in 2009 that it was time to review the model. The objectives of the review were to improve the consistency in the naming and units of the variables, to update the elasticities, to introduce tropical oilseeds, meals and oils, to adopt a generic template for building model equations (while keeping the market and policy specificities of the Aglink countries) and, finally, to change the structure of the model so as to clear markets on prices and no longer on trade. This last change facilitated the analysis of bilateral trade policies and a better specification of tariff-rate quotas.

Later, the feed demand system was completely revised. The new system brought the following improvements: introduction of new feeds, mostly by-products of existing food and fuel processing (in particular dried distiller's grains, commonly known as DDGs), updated elasticities, possible substitution of fodder feeds in some countries, links with fishmeal and the feed requirement of the fast-growing aquaculture industry and, more importantly, consistency between animal requirements and feed consumed. Finally, cotton was introduced in 2013, and three new countries were added to the EU component, namely Romania, Bulgaria and Croatia.

At the same time as the review, the OECD and the European Commission made an effort to improve the documentation of the model, which resulted in the production of this report by the European Commission.

Currently, Aglink-Cosimo is one of the most complete and complex dynamic partial equilibrium models of world agricultural markets. It also seems fairly likely that new components will be added to the core model in the future. Desirable modifications would be the introduction of fish consumer prices in the meat demand functions, in order to ensure full complementarity between Aglink-Cosimo and the satellite fish module, the inclusion of greenhouse gas emissions, and complete land use coverage. Other satellite modules will probably join the Aglink-Cosimo family in the near future, such as some tropical fruits, potatoes and a more disaggregated fish market model.

Pierre Charlebois

1. Introduction

1.1 Background

1.1.1 Aglink-Cosimo modelling system

Aglink-Cosimo is a recursive-dynamic, partial equilibrium, multi-commodity market model of world agriculture. The model integrates the Organisation for Economic Cooperation and Development's (OECD's) Aglink and the Food and Agriculture Organization of the United Nation's (FAO's) Cosimo sub-modules. It is managed by the OECD and FAO Secretariats. The model is used to simulate the development of annual supply, demand and prices for the main agricultural commodities produced, consumed and traded worldwide. The Aglink-Cosimo model is currently composed of around 36 000 equations. It covers 44 individual countries and 12 regions (see Annex 1), 93 commodities (see Annex 2) and 40 world market clearing prices (see Annex 3). The Aglink-Cosimo country and regional modules and projections are developed and maintained by the OECD and FAO Secretariats in conjunction with country experts in national administrations.

Specifically, the Aglink component of the model consists of 12 endogenous and 2 exogenous modules: 10 OECD countries/regions (Australia, Canada, EU-28, Switzerland, Norway, Japan, Korea, Mexico, New Zealand and the USA) and four non-OECD countries (Argentina, Brazil, China and Russia). The Cosimo component of the model consists of 42 endogenous modules: three OECD members (Chile, Israel and Turkey), 27 non-OECD countries and 12 regional aggregates (see Annex 1).

The purpose of the present report is to document the EU module (EU-28), which consists of the 28 Member States and is composed of two endogenous modules, one for the former 15 Member States (EU-15) and another one for the 13 new Member States (EU-N13). In particular, supply and demand functions are specific to the EU-15 and NMS-13 aggregates, with trade and stocks being determined endogenously for the EU-28 at the aggregate level[1].

1.1.2 Outlook and baseline process

An important activity of the European Commission is the annual production of medium-term (10-year) baseline projections for agricultural commodity markets (*Prospects for Agricultural Markets and Income in the EU* (hereafter known as the EU Outlook), published annually by the European Commission's Directorate General for Agriculture and Rural Development (DG AGRI) in the second half of the year. Aglink-Cosimo, and in particular its EU module, is the key model for building these baseline projections and performing uncertainty analysis around them.

This exercise serves as an input to the EU contribution (i.e. questionnaire) to the annual OECD/FAO Agricultural Outlook exercise, which is carried out during the first half of each year and has a broader scope than the EU Outlook.

The process of obtaining a baseline starts with the release by the OECD/FAO of the latest medium-term baseline, corresponding model and data in June of each year. From here, the process of producing an EU baseline can be summarised in four steps:

1. The first step consists in expanding the OECD/FAO baseline by one year and recalibrating the EU component by taking into account the following information: (i) an updated and consistent set of medium-term macroeconomic projections; and (ii) additional information coming from the short-term EU Outlook (i.e. 6- to 18-month forecasts of EU agricultural market development generated by the market units at DG AGRI, based on the latest knowledge and expertise available on market and price developments). This leads to a preliminary baseline that could slightly deviate from the short-term EU Outlook, mainly because the system of equations is solved simultaneously and only the EU component is recalibrated, so

1 Please note that no intra-trade is modelled in Aglink-Cosimo.

that changes in net trade with the EU may lead to changes in domestic and world prices. Moreover, the closure of market balances in Aglink-Cosimo will ensure that any inconsistency in the short-term EU Outlook is removed.

2. The second step corresponds to a review of the preliminary baseline obtained in step 1 by interacting with commodity experts (i.e. market experts on arable crops, sugar and biofuels, meat, milk and dairy products). A key input into the baseline projections is the up-to-date input of commodity market judgements by DG AGRI experts. The inputs collected are incorporated into the baseline, which will serve as a starting point for the calibration of other models (e.g. CAPRI[2] or AGMEMOD[3] models) and for the development of uncertainty analyses.

3. The preliminary baseline produced in step 2 is the basis of an EU Outlook workshop jointly organised by DG AGRI and the Joint Research Centre Institute for Prospective Technological Studies (JRC-IPTS), gathering policy makers, modellers, market experts and stakeholders of international relevance. The workshop offers an opportunity to verify the reliability of the results obtained and to discuss how different settings and assumptions regarding macroeconomic factors and other uncertainties may influence the projections of individual commodity markets. As part of the validation procedure, suggestions and comments made during the workshop are taken into account in order to improve the baseline projections.

4. The last stage consists of publishing the final projections in DG AGRI's EU Outlook. These projections are then used as the European Commission's questionnaire for the following OECD/FAO Agricultural Outlook.

1.2 Regions, commodities and items of the EU module

In Aglink-Cosimo, variables contain four dimensions: 'regions', 'commodities', 'items' and 'years'. Usually, the dimensions 'regions' and 'commodities' serve as identifiers for behavioural equations, with the dimension 'items' defining the type of equation. All equations are solved for all 'years' within the simulation period (e.g. 2015–2024 in the latest EU Outlook). As an example, in order to measure the soft wheat yield in the 13 new Member States, the variable is written as NMS_WTS_YLD, where NMS stands for the EU-N13, WTS for soft wheat and YLD for yield. Note the order of the dimensions in the variable name: region, commodity and item. This order is a convention adopted by the Aglink-Cosimo team, and should be respected, as it allows an automated generation of the template code and splitting of variable dimensions for reporting and post-model analysis.

Aglink is a recursive-dynamic partial equilibrium model; this implies that every variable has a certain value for a specific year. Lagged values of the variables affecting the contemporaneous year are considered exogenous; therefore, for every year the model is solved separately.

In the following subsections, more detailed information is given concerning the first three dimensions, their components and the relations among them in creating the different elements that form the model.

1.2.1 Regions

The Aglink EU module covers three regions E15 (for EU-15, the 15 older Member States), NMS (for EU-N13, the 13 new Member States) and EUN (for EU-28), where the last one is the aggregate of the first two. Certain links between the EU and the rest of the model require variables with additional geographic information, such as the following:

- In the EU meat module, two additional regions are considered, Pacific (PAC) and Atlantic (ATL), reflecting different markets for meat products on the basis of their different animal health regimes, which have an impact on the potential for trade.

- In the EU feed module and the cost of production index equations, the USA is included.

- In the EU market closure equations, the region 'world' is included.

The full list of regions included in the EU module and their acronyms is included in Annex 4.

2 www.capri-model.org

3 www.agmemod.eu

1.2.2 Commodities

The Aglink EU module covers 90 commodities, ranging from crops such as wheat or oilseeds, to processed goods or by-products such as protein meals and dried distiller's grains. Prices for two additional non-agricultural commodities, crude oil and fertiliser, are included in the EU module. Whereas the price for crude oil (Brent) is exogenous, the world fertiliser price is partly endogenous. The full list of commodities included in the EU module and their acronyms can be found in Annex 4.

1.2.3 Items

The Aglink EU Module covers 250 items that serve as the definition component of the behavioural equations. Unlike the previous two dimensions, which are homogeneous groups, the dimension item is very heterogeneous, ranging from very general measurements, such as 'yield' or 'returns per hectare', to very specific measurements, such as conversion factors between two commodities for producing a good. Some of the items are very specific and are used only for a single equation or element within an equation; others are less specific and are used in a group of equations (e.g. 'YLD'). Another purpose of the 'item' dimension is to incorporate policy information into the model, i.e. tariffs and quotas that apply to only a limited number of commodities in different ways. In Annex 4 all the items included in the EU module and their acronyms are listed. Annex 5 provides a description of each item of the EU module.

1.3 Elements of the EU module: variables, constants, parameters and residuals

Most behavioural equations in Aglink-Cosimo are 'double-log', which is a convenient linear transformation of a logarithmic function and popular for estimating production and demand functions. In these functions both the explanatory and the explained variables are expressed in logarithmic terms:

$$Log\ (Y) = \xi \cdot log\ (X) + \beta_0 + log\ (R)$$

This is generally appropriate when we believe that the underlying relationship between Y and X resembles a logarithmic function (e.g. Y experiences diminishing marginal returns with respect to increases in X). This is altered only by the introduction of an intercept (bo) and slope (ξ), which we call 'constant' and 'elasticity', respectively. It is important to note that, in this model, we consider elasticities constant along the estimated function.

1.3.1 Model variables

Variables in the model can be declared as both endogenous and/or exogenous (TROLL requires only that the model has the same number of endogenous variables as it has of linear independent equations). Declaring endogenous variables suffices, as all other variables are considered exogenous (e.g. X in our previous example), as long as the coefficients and parameters have been well identified. The EU module currently has 1 540 endogenous variables (i.e. the 2014 OECD/FAO model version).

1.3.2 Model constants

The constants in Aglink-Cosimo are used as scaling parameters and are typically re-estimated during the baseline process so as to scale the error terms on 1 over the projection period. Please note here the interplay between the constant and the error terms, something to take into account when interpreting results (i.e. they cannot be understood separately).

1.3.3 Model parameters

The Aglink-Cosimo model, in common with many other commodity models, is elasticity driven. As mentioned above, one of the nice properties of 'double-log' functions is that elasticities can be explicitly used. In the Aglink-Cosimo model there are elasticities for most behavioural equations, for example price–yield elasticities (C.E15_WTD_YLD.E15_WTD_PP for durum wheat in the EU-15) and price–demand elasticities (e.g. C.E15_WT_FO.E15_CG_CP for food demand in the EU-15 and C.E15_WT_FE.EUN_WT_PP for feed demand in the EU-15). By convention, all parameters in the model have the string 'C.' at the beginning.

Additional parameters in the model are trends that reflect technological change or changes in taste. Trends are specific to every behavioural equation.

1.3.4 Model residuals

The residuals or error terms of the behavioural equations are considered in Aglink-Cosimo as 'special variables' and by convention start with the string 'R.' (e.g. R.E15_WT_FE for feed use of wheat in the EU-15). Residuals are considered 'exogenous variables' during simulation and 'endogenous variables' during calibration. This is why they are also called 'calibration factors', as they are used to produce the medium-term baseline. Aglink-Cosimo is very flexible in this respect, as residuals are different for each behavioural equation and year.

2. Description of core model

2.1 Structural characteristics of EU agricultural supply

2.1.1 Costs of production

Aglink-Cosimo does not have explicit cost functions per commodity and region. In order to account for input costs, a cost of production index approach is built. The production cost index is different for each crop product and is constructed from five sub-indices representing seed inputs, fertiliser inputs, energy inputs, other tradable inputs and non-tradable inputs.

$$
\begin{aligned}
&CPCI_{c,r,t} = \\
&CPCS..SHSD_{c,r,t} \cdot PP_{c,r,t-1}/PP_{c,r,2007} + \\
&CPCS..SHEN_{c,r,t} \cdot \left(XP_{oil,wld,t} \cdot XR_{r,t}\right)/\left(XP_{oil,wld,2008} \cdot XR_{r,2008}\right) \\
&+ CPCS..SHFT_{c,r,t} \cdot \left(XP_{FT,wld,t} \cdot XR_{r,t}\right)/\left(XP_{FT,wld,2008} \cdot XR_{r,2008}\right) \\
&+ CPCS..SHTR_{c,r,t} \cdot \left(GDPD_{USA,t} \cdot XR_{r,t}\right)/\left(GDPD_{USA,2008} \cdot XR_{r,2008}\right) \\
&+ CPCS..SHNT_{c,r,t} \cdot GDPD_{c,r,t}/PP_{c,r,2008}
\end{aligned} \tag{1}
$$

with:

$CPCI_{c,r,t}$	commodity production cost index for commodity *c* in region *r* and year *t*
$CPCS..SHNT_{c,r,t}$	share of non-tradable inputs in total base commodity production costs
$CPCS..SHEN_{c,r,t}$	share of energy in total base commodity production costs
$CPCS..SHFT_{c,r,t}$	share of fertiliser in total base commodity production costs
$CPCS..SHTR_{c,r,t}$	share of other tradable inputs in total base commodity production costs
$CPCS..SHSD_{c,r,t}$	share of seed input in total base commodity production costs
$GPPD_{c,r,t}$	gross domestic product deflator
$XP_{oil,wld,t}$	world crude oil price
$XP_{FT,wld,t}$	world fertiliser price
$PP_{c,r,t-1}$	producer price for crop product c
$XR_{r,t}$	nominal exchange rate with respect to the US dollar

The shares of the various cost categories are country specific. They were estimated based on historical cost structures in individual counties. Although they are called shares, they are really shares only in quantity of inputs and not in terms of expenses, except for the base year (i.e. normalisation year). In other years, including the projection, this cost index is allowed to move up and down depending on the price movement of each input.

The production cost indices employed in Aglink-Cosimo for livestock products are constructed from three sub-indices representing non-tradable inputs, energy inputs and other tradable inputs. The non-tradable sub-index is approximated by the domestic GDP deflator, whereas the energy sub-index is affected by changes in the world crude oil price and the country's exchange rate. Finally, the tradable sub-index is linked to global inflation (approximated by the US GDP deflator) and the country's exchange rate. This relationship is shown in the following equation:

$$CPCI_{c,r,t} = \frac{CPCS..SHEN_{c,r,t} \cdot (XP_{oil,wld,t} \cdot XR_{r,t})}{(XP_{oil,wld,2008} \cdot XR_{r,2008})} + \frac{CPCS..SHNT_{c,r,t} \cdot GDPD_{c,r,t}}{PP_{c,r,2008}} + \frac{(1 - CPCS..SHNT_{c,r,t} - CPCS..SHEN_{c,r,t}) \cdot (GDPD_{USA,t} \cdot XR_{r,t})}{(GDPD_{USA,2008} \cdot XR_{r,2008})} \quad (2)$$

with:

$CPCI_{c,r,t}$	commodity production cost index for commodity c in region r and year t
$CPCS..SHNT_{c,r,t}$	share of non-tradable inputs in total base commodity production costs
$CPCS..SHEN_{c,r,t}$	share of energy in total base commodity production costs
$GDPD_{c,r,t}$	gross domestic product deflator
$XP_{oil,wld,t}$	world crude oil price
$XR_{r,t}$	nominal exchange rate with respect to the US dollar

The list of costs considered in each cost category of Aglink-Cosimo is explained in Table 1. The feed costs are endogenous to the model, and therefore they are not considered in these shares. The cost of animal purchase was discarded, as each animal sector is considered at the macro level. The total cost of labour is included; thus, own labour is accounted for at its opportunity cost. Land and capital costs are not included except for depreciation.

Table 1: Costs of production covered in Aglink-Cosimo

Aglink-Cosimo	Correspondence with the costs in FADN
Energy	Electricity and fuels
Fertilisers	Fertilisers and soil improvers
Seeds	Seeds and seedlings purchased as well as those produced and used on the farm
Other tradables	Crop protection products, other specific crop costs, veterinary costs and other specific livestock costs, machinery and buildings[4]
Non-tradables	Contract work, other farming overheads, depreciation, wages and own work

The cost shares for the EU were revised in 2012 and are based on FADN (Farm Accountancy Data Network).[5] Production costs per activity are not directly available in FADN. Therefore, the Economic Analysis Unit of DG AGRI has developed several models to estimate costs (and margins) for various products: arable crops, milk and beef, pig meat and permanent crops. However, no model covers all the commodities covered in Aglink-Cosimo and, in addition, the model can be applied only if there are enough farms specialised in the product category. For this reason some assumptions are necessary.[6]

At the time of the update, the latest year for which data were available was 2008 (along with estimates for 2009 and 2010). Historic values have been introduced in the model for all years between 2001 and 2010. Beyond 2010, the average for 2000–2010 is used (see Table 2).

4 'Machinery and buildings' include the purchase costs of small equipment (which can be considered as tradable) but also the cost of only repairs (not tradable). Given already the large share of non-tradable and the difficulty of separating this item from the rest, it has been added to the tradable costs category.

5 The aim of this network is to gather accountancy data from farms for the determination of incomes and business analysis of EU agricultural holdings. Currently, the annual sample covers approximately 80 000 holdings, representing about 5 million farms. Available online: http://ec.europa.eu/agriculture/rica/concept_en.cfm

6 Soft wheat is used as a reference for rapeseed, sunflower and sugar beet. For soybean costs, shares are derived from soft wheat but with a different share of fertilisers re-attributed to tradable and non-tradable. Barley is the reference for oats and other cereals. Beef (breeding and fattening) is the reference for sheep and goat meat. Pig fattening is the reference for poultry meat.

Table 2: Costs shares per EU commodity (%)						
		Energy	**Fertilisers**	**Seeds**	**Other tradables**	**Non-tradables**
Soft wheat	EU-15	6.6	13.6	5.7	20.6	53.4
	EU-N13	12.0	19.3	7.1	17.3	44.3
Durum wheat	EU	7.8	9.8	8.3	9.3	64.9
Maize	EU-15	6.8	10.9	7.8	11.8	62.6
	EU-N13	14.6	14.7	10.5	14.4	45.7
Barley	EU-15	8.5	13.3	6.8	10.9	60.4
	EU-N13	11.1	14.5	8.1	12.5	53.8
Oats and other cereals	EU-15	8.5	13.3	6.8	10.9	60.4
	EU-N13	11.1	14.5	8.1	12.5	53.8
Rapeseed Sunflower and sugar beet	EU-15	6.6	13.6	5.7	20.6	53.4
	EU-N13	12.0	19.3	7.1	17.3	44.3
Soybean	EU-15	6.6	5.0	5.7	23.5	59.2
	EU-N13	12.0	5.0	7.1	22.0	53.9
Beef and veal	EU-15	6.1			16.3	77.7
	EU-N13	3.6			4.4	92.0
Sheep meat	EU-15	6.1			16.3	77.7
	EU-N13	3.6			4.4	92.0
Pig meat	EU-15	8.1			21.8	70.1
	EU-N13	5.4			16.3	78.3
Poultry	EU-15	8.1			21.8	70.1
	EU-N13	5.4			16.3	78.3
Milk	EU-15	6.8			18.1	75.1
	EU-N13	13.2			16.2	70.6

2.1.2 Arable crop production

The arable crop module covers grains, oilseeds and sugar beet, whose production is endogenous to the model. The grains include coarse grains (i.e. maize, barley, oats, rye and other cereals), wheat (i.e. soft wheat and durum wheat), cotton and rice. Oilseeds include rapeseed, soybean and sunflower seed. Other crops such as fruit and vegetables are included in the model exogenously.

Production, $QP_{c,r,t}$, is obtained by multiplying the area harvested ($AH_{c,r,t}$) by the yield ($YLD_{c,r,t}$) such that:

$$QP_{c,r,t} = AH_{c,r,t} \cdot YLD_{c,r,t} \qquad (3)$$

Farmers adjust the quantity of input based on production margins, as the output price is divided by the index of input prices. Yield is modelled such that it adjusts with respect to this ratio in the previous year (t – 1), which reflects the margin expectation of the farmer at the time of making production decisions:

$$Log\left(YLD_{c,r,t}\right) = a \quad + \xi_{YLD,PP} \cdot Log\left(\frac{PP_{c,r,t-1}}{\xi_{CPCI}CPCI_{c,r,t-1} + (1-\xi_{CPCI})CPCI_{c,r,t}}\right)$$
$$+trend \quad + R_{Y,r,c} \tag{4}$$

$Y_{c,r,t}$ denotes the yield for the commodity c in region r in year t, $a_{c,r,t}$ is a constant, $\xi_{Y,p}$ is the yield to price elasticity, $P_{c,r,t-1}$ is the price of the commodity c in region r in the year t – 1, ξ_{CPCI} is the share of the production cost index of a calendar year consistent with the crop year, $CPCI_{c,r,t}$ and $CPCI_{c,r,t-1}$ are the cost of production index for commodity c in region r in year t and t – 1 respectively, $trend_{c,r,t}$ is a time trend and $R_{Y,r,c}$ is the calibration parameter for the variable yield Y in region r and for commodity c.

The price is deflated with the current and the previous cost of production index. Therefore, yield depends on the inputs used in both the planting year and the harvesting year. Apart from the price component of the equation, a time trend is included, which is an approximation of technological change assumed to have a positive effect on the yield. In contrast to many equations, the trend is not logarithmic, which reflects the importance of the trend in the development of yields.

The area allocation is determined by the relative competitiveness of the different crops and pasture evaluated on a per hectare basis. Therefore, improvements in yields are taken into account through the price effects as well as set-aside policy assumptions. In Aglink-Cosimo, the area allocation system is symmetrical, which means that the partial derivative of all the two cross-price elasticity combinations have been forced into equality. This ensures a system of cross-price elasticities that will respect the relative weight of each crop in the land allocation of the different countries (i.e. this condition of symmetry prevents, for instance, a much stronger reaction in the consumption of lamb owing to a 1% change in the price of beef than the reverse situation). Moreover, the area allocation system is not homogeneous of degree zero (i.e. the sum of all own and cross-partial derivatives is not equal to zero), allowing for a potential expansion in arable land depending on the land endowments of the country modelled and considering that the model does not cover all the crops planted in the countries concerned:

$$\xi_{AH..SHR_A,RH_B} = \frac{\partial AH..SHR_A}{\partial RH_B} \cdot \frac{RH_B}{AH..SHR_A} \tag{5}$$

In the EU model, the area allocation system is slightly different from that followed in other Aglink-Cosimo regions. Area is allocated to a given crop c depending on its relative competeviness with soft wheat, which is the main crop in the EU and is, therefore, used as a point of reference for all other arable crops, drastically reducing the number of elasticities to parameterise in the area equations. However, this omits possible competition for land between the other crops (e.g. maize with soybean or maize with sunflower). This is equivalent to a cross-price effect and competition for land among crops. The area allocation is done by calculating the area share (AH..SHR) for crop c in region r, denoted as $AH..SHR_{c,r,t}$ such that:

$$Log\left(AH..SHR_{c,r,t}\right) = a + \xi_{AH..SHR,RH_{WTS}}$$
$$\cdot Log\left(\frac{RH_{c,r,t-1}+EPA_{c,r,t-1}}{\xi_{CPCI}CPCI_{c,r,t-1}+(1-\xi_{CPCI})CPCI_{c,r,t}} \Big/ \frac{RH_{WTS,r,t-1}+EPA_{WTS,r,t-1}}{\xi_{CPCI}CPCI_{WTS,r,t-1}+(1-\xi_{CPCI})CPCI_{WTS,r,t}}\right)$$
$$+trend + R_{AH..SHR,r,c} \tag{6}$$

with $\xi_{AH..SHR,RH_{WTS}}$ denoting the area share of crop c to soft wheat returns per hectare elasticity, $RH_{c,r,t-1}$ the returns per hectare, $EPA_{c,r,t-1}$ the area payment equivalent and $CPCI_{c,r,t}$ the cost of production index.

Note that, as soft wheat is used as a reference for allocating the area for all the crops, its area share is calculated by subtracting the sum of all the area shares from 1, that is :

$$AH..SHR_{WTS,r,t} = 1 - \sum_{c \neq WTS}(AH..SHR_{c,r,t}) \tag{7}$$

In order to calculate the harvested area denoted as , the area share is multiplied by the total arable crop land available for cereals, oilseeds and fodder after deduction of the non-cultivated arable land/ fallow land (e.g. set-aside) as follows:

$$AH_{c,r,t} = AH..SHR_{c,r,t} \cdot (AH_{crops,r,t} - AH_{set,r,t}) \tag{8}$$

where $AH_{crops,r,t}$ is the available arable land for crops and $AH_{set,r,t}$ the non-cultivated arable land/ fallow land.

The area harvested for crops is calculated as:

$$AH_{crops,r,t} = AH_{UAA,r,t} - AH_{pasture,r,t} - AH_{others,r,t} \tag{9}$$

where $AH_{agriculture,r,t}$ is the total utilised agricultural area (UAA), $AH_{pasture,r,t}$ is the area under permanent pastures (exogenous) and $AH_{others,r,t}$ is the area harvested for other crops not covered in Aglink-Cosimo, such as fruit and vegetables, vineyards, olive groves, etc. (exogenous).

The set-aside area shall be deducted from the total arable crop area in order to determine the area allocated for each arable crop. The set-aside area is obtained by applying the share of set-aside to the total arable crops area, using the formula:

$$AH_{set,r,t} = AH_{crops,r,t} \cdot AH..SHR_{set,r,t} \tag{10}$$

As set-aside is no longer compulsory in the EU, and this has been the case since 2008, the area of land set aside is at the discretion of farmers, whose decision is based on revenue (returns and payments). However, further to the 2013 Common Agricultural Policy (CAP) reform, some greening measures, such as the ecological focus area (EFA), could result in additional land area being set aside. The model allows for this possibility via an exogenous variable named , reflecting the set-aside policy choice. The share of set-aside area is thus calculated as:

$$AH..SHR_{set,r,c} = a + \xi_{AH..SHRset,RCcrops} \cdot Log(RH_{crops,r,t-1} + EPA_{agriculture,r,t-1}) + trend + Log(AD..SHR_{set,r,t}) + R_{AH..SHR,r,set} \tag{11}$$

where $\xi_{AH..SHRset,RHcrops}$ is the elasticity of the set-aside area share to the returns per hectare for crops, $RH_{crops,r,t-1}$ is the return per hectare for crops, $EPA_{agriculture,r,t-1}$ is the area payment, $AD..SHR_{set,r,t}$ is the additional share of policy-driven set-aside and a, $trend$ and R are the constant, trend and residual, respectively.

The revenue per crop and region, which as mentioned above drives both the crop area share and the set-aside area, is composed of two elements: the area payments and returns per hectare, denoted as $RH_{c,r,t}$. Crop returns are calculated as a three-year weighted average, to remove the effect of the strong variability in yields and prices, as follows:

$$RH_{c,r,t} = 0.5 \cdot PP_{c,r,t} \cdot YLD_{c,r,t} + 0.3 \cdot PP_{c,r,t-1} \cdot YLD_{c,r,t-1} + 0.2 \cdot PP_{c,r,t-2} \cdot YLD_{c,r,t-2} \tag{12}$$

where $P_{c,r,t}$ is the price of the crop c in region r in year t and $Y_{c,r,t}$ is the yield of the crop c in region r in year t.

The area payments ($EPA_{c,r,t}$) are the sum of coupled payments $EPA..DP_{c,r,t}$ and decoupled payments $EPA_{agriculture,r,t}$. Coupled payments in the arable sector are currently significant only for cotton[7]:

$$EPA_{c,r,t} = EPA_{agriculture,r,t} + EPA..DP_{c,r,t} \tag{13}$$

Based on OECD work, it is assumed that decoupled payments (Single Farm Payment or SFP[8]) have a small effect on production, currently set at 6 % ($SFP..CF_{agriculture,r,t}$). Only this share of the single farm payment $SPF_{agriculture,r,t}$, is added to the crop revenue:

$$EPA_{agriculture,r,t} = SPF_{agriculture} \cdot SFP..CF_{agriculture,r,t} \tag{14}$$

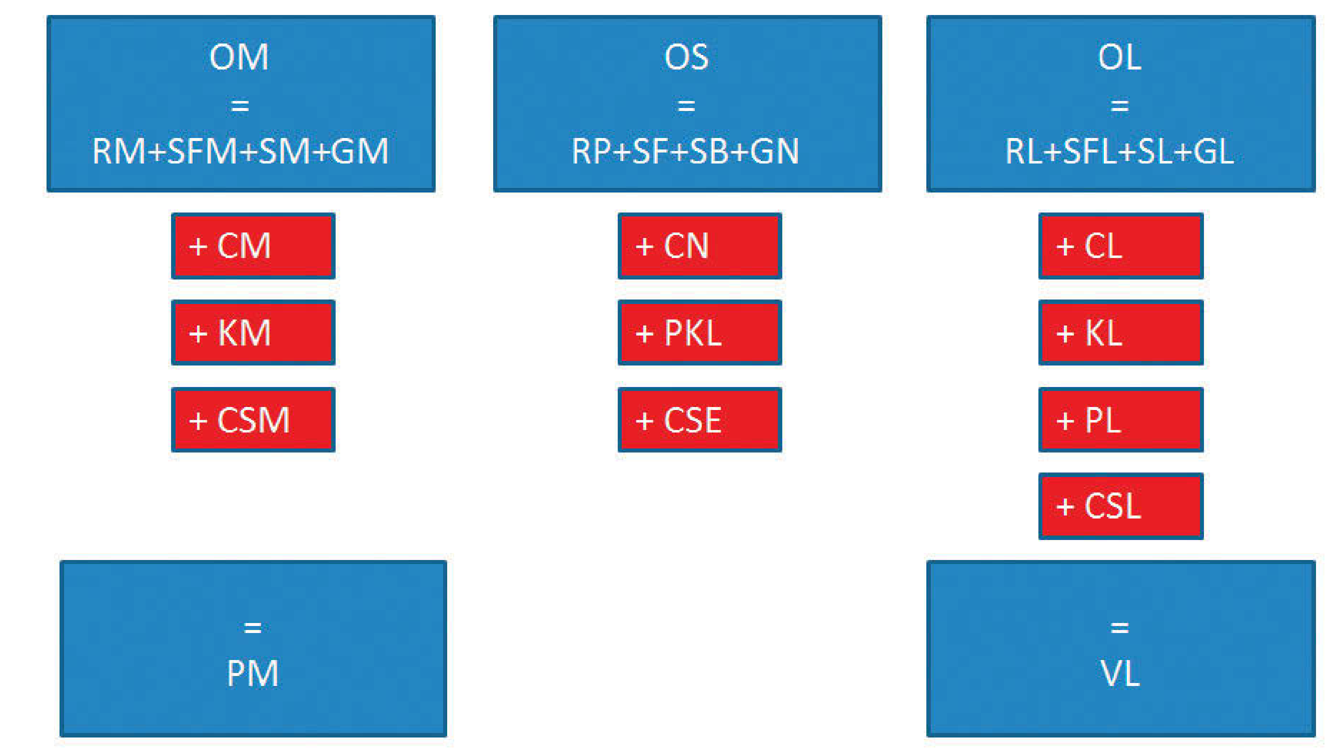
7 Rice payments have been fully decoupled since 2012. Only a few Member States use Article 68 or Complementary National Direct Payments to grant coupled payments to crops.

8 The Single Area Payment Scheme (SAPS), which applies in several Member States of the EU-N13, is modelled as a SFP.

2.1.3 Production of vegetable oils and protein meals

The total production of vegetable oils in Aglink-Cosimo is the aggregate of oilseeds oils (rapeseed oil, sunflower oil, soybean oil and groundnut oil), coconut oil, palm kernel oil, palm oil and cottonseed oil (see Figure 1).

Figure 1: Details of the oilseeds aggregate in Aglink-Cosimo



OM	Oil meals		OS	Oilseeds		OL	Oilseed oils
RM	Rapeseed meal		RP	Rapeseed		RL	Rapeseed oil
SFM	Sunflower meal		SF	Sunflower seed		SFL	Sunflower oil
SM	Soybean meal		SB	Soybean		SL	Soybean oil
GM	Groundnut meal		GN	Groundnut		GL	Groundnut oil
CM	Copra (coconut) meal		CN	Copra (coconut)		CL	Copra (coconut) oil
KM	Palm kernel meal		PKL	Palm kernel		KL	Palm kernel oil
CSM	Cotton seed meal		CSE	Cotton seed		PL	Palm oil
						CSL	Cotton seed oil
PM	Protein Meals					VL	Vegetable oils

In the EU model, palm oil and palm kernel oil supply is considered to be zero. Furthermore, supplies of coconut and groundnut oils are exogenous to the model. The oil production results from the quantity of oilseeds crushed () multiplied by the yield ():

$$QP_{oil,r,t} = CR_{c,r,t} \cdot YLD_{oil,r,t} \tag{15}$$

The quantity of crop (sunflower, soybean and rapeseed) crushed is dependent on the crushing margin and the elasticity relative to that crushing margin:

$$\begin{aligned} Log\left(CR_{c,r,t}\right) = a \quad &+ \xi_{CR_C,CRMAR_{SF}} \cdot Log\left(\frac{CRMAR_{SF,r,t}}{GDPD_{r,t}}\right) \\ &+ \xi_{CR_C,CRMAR_{SB}} \cdot Log\left(\frac{CRMAR_{SB,r,t}}{GDPD_{r,t}}\right) + \xi_{CR_C,CRMAR_{RP}} \cdot Log\left(\frac{PCRMARP_{RP,r,t}}{GDPD_{r,t}}\right) \\ &+ trend \quad + R_{CR,r,c} \end{aligned} \tag{16}$$

The crushing margin ($CRMAR_{c,r,t}$) is calculated as a weighted average of the revenues obtained from each processed product (i.e. price multiplied by yield divided by the price of the oilseeds crushed):

$$CRMAR_{c,r,t} = \frac{\left(PP_{OL,r,t} \cdot YLD_{OL,r,t} + PP_{PM,r,t} \cdot YLD_{PM,r,t}\right)}{PP_{c,r,t}} \tag{17}$$

where $PP_{OL,r,t}$ represents the price of soybean, sunflower and rapeseed oils, $PP_{PM,r,t}$ the price of soybean, sunflower and rapeseed meals (endogenous to the model), while $YLD_{OL,r,t}$ and $YLD_{PM,r,t}$ represent the yield of oil and protein meal, respectively, for the three oilseeds concerned (see table 3).

Table 3: Vegetable oils and protein meal yields in the EU

	EU-15	EU-N13
Oilseed oil *	**0.32**	**0.41**
Soybean oil	0.19	0.19
Sunflower oil	0.42	0.42
Rapeseed oil	0.42	0.42
Groundnut oil	0.43	–
Cottonseed oil	0.16	–
Oilseed meal *	**0.65**	**0.55**
Soybean meal	0.79	0.79
Sunflower meal	0.52	0.52
Rapeseed meal	0.56	0.56
Groundnut meal	0.57	–
Cottonseed meal	0.52	–
Soybean meal	0.79	0.79

** Include soybean, sunflower, rapeseed and groundnuts*

Oilseeds meals are an aggregate of soybean, rapeseed, sunflower and groundnut meals. Then total production of protein meals is an aggregate of oilseed meals plus coconut, cottonseed and palm kernel meals. The representation the production of oilseeds meals in the model is similar to the above description for vegetable oils.

2.1.4 Production of sugar beet and sugar

The European sugar market is modelled in Aglink, taking into account the EU regulations applicable to the sector, namely production quotas and support prices (following the principles described hereafter in the section on prices).

Sugar production is calculated as a function of sugar beet production only, i.e. not including sugar cane, as production of sugar cane in the EU is estimated to be zero, such that:

$$QP_{SU,r,t} = (QP_{SEBr,t} - BF_{SBE,r,t}) \cdot YLD_{SBE,r,t} \tag{18}$$

where $YLD_{SBE,r,t}$ is the sugar extraction rate, $BF_{SBE,r,t}$ the quantity of sugar beet used for biofuels and $QP_{SEBr,t}$ is sugar beet production. Sugar beet production is modelled in the same way as other arable crops using the sugar beet price, $PP_{SBE,r,t}$, to calculate the yield, while land allocation is modelled in the same way as for other arable crops by reference to revenue from common wheat.

On the one hand, when the production quota is not binding, sugar beet production is modelled like the other arable crops. On the other hand, if the quota is binding, the price is determined by policy parameters and the sugar beet surplus ends up in the biofuel sector. The production of sugar beet under quota ($QT_{SBE,r,t}$) is modelled as a function of the sugar quota ($QT_{SU,r,t}$) and the sugar yield ($YLD..SBE_{SU,r,t}$) in the following way:

$$\mathrm{QT}_{SBE,r,t} = \mathrm{QT}_{SU,r,t}/\mathrm{YLD..SBE}_{SU,r,t} \tag{19}$$

The sugar quota is exogenous and its value is 12.115 and 2.590 million tonnes for the EU-15 and EU-N13, respectively. Sugar yields are also exogenous and equal to 0.179 and 0.172 t/ha for the EU-15 and EU-N13, respectively.

Following the reforms to be enforced in 2017, production quotas will be set to zero, which will probably have a positive impact on sugar beet production in the EU. This will also have an impact on sugar prices, which will no longer be dependent on the support price, as will be explained in the sections on prices, and on the overall market balance.

2.1.5 Production of milk and dairy products

The dairy component in Aglink covers production and consumption of milk and its main dairy products. Like the markets of other commodities, dairy markets are modelled specifically to best capture individual policies and particular market settings relevant for each country. Generally, milk production is expressed as the product of the milk cow inventory and milk yields. However, in the EU (as in Canada), milk production is determined not by producer decisions but by production quotas, which are considered binding.

Milk quotas in the EU are modelled in Aglink at the EU-15 and EU-N13 aggregated levels. Although some Member States have overshot their quotas, the total sum of quota delivered has not been exceeded at the EU-N13 or EU-15 levels. Furthermore, following the reform of the CAP, no milk quotas have been included in Aglink beyond 2015.

Before quota expiry in 2015, if the delivery quota ($DEL..QT_{MK,r,t}$) is binding for the EU-15 or the EU-N13, milk production ($QP_{MK,r,t}$) is obtained by summing the quota for deliveries ($DEL..QT_{MKr,t}$) and the milk used on farm ($FU_{MKr,t}$):

$$QP_{MKr,t} = DEL..QT_{MKr,t} + FU_{MK,r,t} \tag{20}$$

The farm use of milk ($FU_{MKr,t}$) gathers together feed use (FE), direct sales (QP..DS) and any other use (OU). Feed use depends on the dairy cow inventory for year $t-1$. Milk direct sales are exogenous to the model. Other uses at farm level depend on milk prices and their evolution with respect to price indices.

From 2015 onwards, the EU milk production quota expires and cow's milk production will be calculated as the sum of milk production from dairy cows and milk from non-dairy cows (the latter being exogenous):

$$QP_{MK,r,t} = CI..NQT_{MK,r,t} \cdot YLD_{MK,r,t} + QP..OTH_{MK,r,t} \tag{21}$$

where $CI..NQT_{MK,r,t}$ is the dairy cow inventory when milk quota is not binding, $YLD_{MK,r,t}$ is the milk yield and $QP..OTH_{MK,r,t}$ is the production of non-dairy cows (i.e. 'other cows').

The production of dairy cows is therefore a function of two endogenous variables: (1) the milk yield ($YLD_{MK,r,t}$) and (2) the number of dairy cows, basically the dairy cow inventory in a post-quota environment after 2015 ($CI..NQT_{MK,r,t}$)

Following the general specification in Aglink-Cosimo, milk yields in the EU component are calculated as a function of the revenue from milk in the same year (i.e. price and subsidies) and of the cost of feeding ruminants, both deflated by the cost of the production index for milk:

$$Log(YLD_{MK,r,t}) = a \quad + \xi_{YLD_{MK},PP_{MK}} \cdot Log\left(\frac{PP_{MK,r,t} + EPY_{MK,r,t}}{CPCI_{MK,r,t}}\right) + \xi_{YLD_{MK},FECI_{RU}} \cdot Log\left(\frac{FECI_{RU,r,t}}{CPCI_{MK,r,t}}\right) + trend \quad + R_{YLD,MK,r} \tag{22}$$

where $PP_{MK,r,t}$ is the domestic price of milk is the milk, $EPY_{MK,r,t}$ unit payment equivalent relevant to yields (exogenous), $FECI_{RU,r,t}$ is the feed cost index applicable for ruminants and $CPCI_{MK,R,T}$ is the milk production cost index.

The number of dairy cows (i.e. milk cow inventory) depends on several variables: first, the revenue from milk activity for the current year and for the previous year; second, the revenue from beef meat production; and, third, the feed cost for ruminants for the same year and for the previous year all deflated by the milk production cost index:

$$\begin{aligned} Log(CI..NQT_{MK,r,t}) = {} & a \quad + \xi_{CI..NQT_{MK},PP_{MK}} \cdot Log\left(\frac{PP_{MK,r,t} + EPY_{MK,r,t}}{CPCI_{MK,r,t}}\right) \\ & + \xi_{CI..NQT_{MK},PP-1_{MK}} \cdot Log\left(\frac{PP_{MK,r,t-1} + EPY_{MK,r,t-1}}{CPCI_{MK,r,t-1}}\right) \\ & + \xi_{CI..NQT_{MK},PP_{BV}} \cdot Log\left(\frac{PP_{BV,r,t} + EPQ_{BV,r,t}}{CPCI_{MK,r,t}}\right) \\ & + \xi_{CI..NQT_{MK},FECI_{RU}} \cdot Log\left(\frac{FECI_{RU,r,t}}{CPCI_{MK,r,t}}\right) \\ & + \xi_{CI..NQT_{MK},FECI-1_{RU}} \cdot Log\left(\frac{FECI_{RU,r,t-1}}{CPCI_{MK,r,t-1}}\right) + Log\left(R_{CI..NQT,MK,r}\right) \end{aligned} \tag{23}$$

where $PP_{MK,r,t}$ is the domestic price of milk, $PP_{BV,r,t}$ is the domestic price of beef meat, $EPY_{MK,r,t}$ and $EPQ_{BV,r,t}$ are the milk and beef meat unit payment equivalent relevant to yields), respectively, $FECI_{RU,r,t}$ is the feed cost index applicable for ruminants $CPCI_{MK,r,t}$ and is the milk production cost index.

In Aglink-Cosimo, production of dairy products is modelled under the assumption that the values of the main components in milk (i.e. fat and non-fat solids) are equal across products. Butter and skimmed milk powder prices are typically used as proxies for fat and non-fat solids prices, respectively. Therefore, the milk supply is split into the two main components of the milk: fat ($FAT_{MK,EUN,t}$) and non-fat solids ($NFS_{MK,EUN,t}$). The supply of both is calculated using milk production multiplied by the content of fat and non-fat solids in milk:

$$FAT_{MK,EUN,t} = \frac{(QP_{MK,EU-15,t} \cdot FAT_{MK,EU-15,t} + QP_{MK,NMS,t} \cdot FAT_{MK,NMS,t})}{QP_{MK,EUN,t}} \tag{24}$$

$$NFS_{MK,EUN,t} = \frac{(QP_{MK,EU-15,t} \cdot NFS_{MK,EU-15,t} + QP_{MK,NMS,t} \cdot NFS_{MK,NMS,t})}{QP_{MK,EUN,t}} \tag{25}$$

Dairy products modelled in Aglink-Cosimo include butter, cheese, skimmed milk powder (SMP), whole milk powder (WMP), casein and whey powder.

For butter, cheese from cow's milk), SMP and WMP, production is modelled as a function of the relative price of the commodity with respect to the price of the fat and non-fat solids. The general formula is :

$$Log(QP_{c,r,t}) = a \quad + \xi_{QP_C,PP..FAT_c} \cdot Log\left(\frac{PP_{c,r,t}}{PP..FAT_{MK,r,t}}\right)$$
$$+\xi_{QP_C,PP..NFS_c} \cdot Log\left(\frac{PP_{c,r,t}}{PP..NFS_{MK,r,t}}\right) + R_{QP,r,c} \tag{26}$$

where $PP_{c,r,t}$ is the domestic price of dairy products commodities, and $PP..FAT_{MK,r,t}$ and $PP..NFS_{MK,r,t}$ the prices for fat and non-fat solids, respectively. The elasticities relate to the importance of fats and non-fat solids in the dairy products. For instance the fat price–supply elasticity ($\xi_{QPC,PP..FAT_c}$) is higher for cheese than for skimmed milk powder. Similarly, the non-fat price–supply elasticity ($\xi_{QPC,PP..NFS_c}$) is higher for whole milk powder than for butter.

Cheese from milk other than cow's milk ($QP..ND_{CH,r,t}$) is modelled with a time trend. Total cheese production is the sum of cheese from cow's milk and cheese from other milk.

Production of casein is calculated as a function of the price ($PP_{CA,r,t}$) from which the casein subsidy ($EPA_{CA,r,t}$) is subtracted. Finally, whey powder supply is calculated as a function of cheese production.

2.1.6 Production of meat and livestock products

The link between milk and beef production is based on the theory of supply, in which producers invest in breeding stock by retaining cows and heifers from slaughter when the capital value of these animals exceeds their current market value (OECD/FAO, 2007). The capital value of a beef breeding cow is a function of the expected income stream earned from the future sales of calves. The higher the expected value of future beef and milk production, the greater the investment in the breeding herd, which will lower the availability of animals for slaughter in the short run. Therefore, to the extent that current beef prices influence expectations of future beef prices, there is the potential for a negative elasticity of beef supply response in the short run.[9]

In the EU module of Aglink-Cosimo, meat gross production is endogenously calculated for chicken (CK), other poultry (OP), beef and veal (BV), pork (PK) and sheep and goat meat (SH) as a function of the following elements: (i) the returns to production, including producer price ($PP_{c,r,t}$) and subsidy ($EPQ_{c,r,t}$) deflated by the cost of production index ($CPCI_{c,r,t}$); (ii) feed costs represented by the feed cost index ($FECI_{c,r,t}$) for different years; (iii) the previous year's production value ($QP_{c,r,t-1}$); and (iv) a trend; and, for beef, the cow inventory from the two previous years ($CI_{C,r,t-i}$) . The general structure of the equation is the following:

$$Log(QP_{c,r,t}) = a + \sum_{i=0}^{3} \xi_{QP_C,PP_{C,t-i}} \cdot Log\left(\frac{PP_{c,r,t-i}+EPQ_{c,r,t-i}}{CPCI_{c,r,t-i}}\right)$$
$$+\sum_{i=0}^{2} \xi_{QP_C,FECI_{C,t-i}} \cdot Log\left(\frac{FECI_{C,r,t-i}}{CPCI_{r,t-i}}\right) + \sum_{i=0} \xi_{QP_C,CI_{C,t-i}} \cdot Log(CI_{C,r,t-i})$$
$$+\xi_{QP_{C,t},QP_{C,t-1}} \cdot Log(QP_{C,r,t-i}) + trend + R_{QP,r,c} \tag{27}$$

This equation applies differently to each meat sub-sector, with different lags depending on the potential length of the investment decisions, which link to the production cycle:

- In the case of beef and veal, revenues of three different years (t, t – 1 and t – 2)[10], feed cost of three different years (t – 1, t – 2 and t – 3) , the cow inventory for two years for non-dairy cows (t – 1, t – 2) and one year for dairy cows (t – 1) are taken into account.

- In the case of sheep, only the revenue of year t – 1and the feed cost indices of years t – 1and t – 2are taken into account.

9 As, in reality, slaughter is carried out not by farmers but by packing plants, the model could be improved by including an additional marketing variable. It could be defined as slaughter plus net exports of live animals and specified as a function of farm characteristics.

10 The price–supply elasticities considered for bovine meat in the EU-15 and the EU-N13 are 0.02, 0.04 and 0.06, respectively, for the years *t*, *t* – 1 and *t* – 2.

- For poultry, only the revenue and feed cost index are taken into account.

It is important to note that total pork production is represented by adding the net trade in live animals, denoted $NTL_{PK,r,t}$, to the quantity of slaughtered meat ($QPS_{C,r,t}$). The quantity slaughtered represents the net production and is endogenously calculated. Gross production, including net trade of live animals, depends on the number of animals slaughtered ($SHL_{PK,r,t}$) and the carcass weight ($CW_{PK,r,t}$):

$$QPS_{PK,r,t} = SHL_{PK,r,t} \cdot CW_{PK,r,t}/1000 \tag{28}$$

As for slaughtered animals, carcass weights are modelled following the general formula used for calculating supply in other meat sectors. However, while carcass weights depend on revenues and the feed cost index of the current year, the number of slaughtered animals depends on revenues, feed cost index and the number of slaughtered animals in the previous year:

$$\begin{aligned} Log\left(CW_{PK,r,t}\right) &= a + \xi_{CW_{PK},PP_{PK}} \cdot Log\left(\frac{PP_{PK,r,t}+EPQ_{PK,r,t}}{CPCI_{c,r,t}}\right) \\ &+\xi_{cw_{PK},FECI_{NR}} \cdot Log\left(\frac{FECI_{NR,r,t}}{CPCI_{r,t}}\right) + trend + R_{CW,r,c} \end{aligned} \tag{29}$$

$$\begin{aligned} Log\left(SLH_{PK,r,t}\right) &= a + \xi_{SLH_{PK},PP_{PK,t-1}} \cdot Log\left(\frac{PP_{PK,r,t-1}+EPQ_{PK,r,t-1}}{CPCI_{c,r,t-1}}\right) \\ &+\xi_{cw_{PK},FECI_{NR}} \cdot Log\left(\frac{FECI_{NR,r,t-1}}{CPCI_{r,t-1}}\right) \\ &+\xi_{SLH_{PK,t},SLH_{PK,t-1}} \cdot Log\left(SLH_{PK,r,t-1}\right) + R_{CW,r,c} \end{aligned} \tag{30}$$

The livestock inventory ($LI_{c,r,t}$) for pork, poultry and sheep is modelled as a function of meat production plus a trend; the general form is:

$$Log(LI_{c,r,t}) = a + Log(QP_{c,r,t}) + trend + R_{QP,r,c} \tag{31}$$

Beef and veal livestock inventories ($LI_{BV,r,t}$) are defined as a three-year weighted sum of the milk and beef cow inventories ($CI_{MK,r,t}$) and ($CI_{BV,r,t}$). This reflects roughly the fact that young bulls and heifers (i.e. less than two years old) are born in the year before or two years earlier, such that:

$$LI_{BV,r,t} = 1.9 \cdot (CI_{BV,r,t} + CI_{MK,r,t}) + 0.54 \cdot (CI_{BV,r,t-1} + CI_{MK,r,t-1}) + 0.1 \cdot (CI_{BV,r,t-2}) + CI_{MK,r,t-2}) \tag{32}$$

The milk cow inventory is equal to the total milk produced from cows (i.e. total milk production minus milk produced by animals other than cows) divided by the milk yield when the quota is binding. If the quota is not binding, the milk cow inventory follows a normal supply function:

$$CI_{MK,r,t} = \frac{\left(QP_{MK,r,t}-QP..OTH_{MK,r,t}\right)}{YLD_{MK,r,t}} \tag{33}$$

The beef cow inventory for meat production ($CI_{BV,r,t}$) is a function of the returns ($RET_{BV,r,t}$), the feed cost index ($FECI_{C,r,t}$) and the cow inventories for both meat ($CI_{BV,r,t-1}$) and milk production ($CI_{MK,r,t-1}$) in the previous year:

$$Log\left(CI_{BV,r,t}\right) = a + \sum_{i=0}^{2} \xi_{CI_C,RET_{C,t-i}} \cdot Log\left(\frac{RET_{BV,r,t-i}}{CPCI_{c,r,t-i}}\right)$$
$$+ \sum_{i=1}^{3} \xi_{QP_C,FECI_{C,t-i}} \cdot Log\left(\frac{FECI_{C,r,t-i}}{CPCI_{r,t-i}}\right) + \sum_{i=0} \xi_{QP_C,CI_{C,t-i}} \cdot Log\left(CI_{C,r,t-i}\right)$$
$$+\xi_{QP_{C,t},QP_{C,t-1}} \cdot Log\left(QP_{C,r,t-i}\right) + trend + R_{QP,r} \tag{34}$$

Returns are a function of prices ($PP_{BV,r,t}$), subsidies ($EPQ_{BV,r,t}$) and carcass weights ($CW_{BV,r,t}$).

Other poultry production ($QP_{OP,r,t}$) is modelled using the revenue, the feed cost index and the production of the previous year as follows:

$$Log\left(QP_{OP,r,t}\right) = a + \xi_{QP_{OP},PP_{OP}} \cdot Log\left(\frac{PP_{OP,r,t}+EPQ_{OP,r,t}}{CPCI_{c,r,t}}\right)$$
$$+\xi_{QP_{OP},FECI_{NR}} \cdot Log\left(\frac{FECI_{NR,r,t}}{CPCI_{r,t}}\right)$$
$$+\xi_{QP_{OP,t},QP_{OP,t-1}} \cdot Log\left(QP_{OP,r,t-1}\right) + R_{CW,r,c} \tag{35}$$

2.2 Biofuels

2.2.1 EU diesel and gasoline consumption

The projection for consumption of diesel and gasoline comes from the POLES (Prospective Outlook on Long-term Energy Systems) model. The equation described below concerning the endogenous modelling of consumption of diesel and gasoline in Aglink-Cosimo is present only for scenario purposes: different macroeconomic conditions might have an impact on consumption of diesel and gasoline, which subsequently has a direct impact on consumption of biofuels.

EU gasoline and diesel consumption are modelled as a function of own consumer price in real terms, which is the consumer price () deflated with the consumer price index (), the real GDP and a trend term such that:

$$Log\left(QC_{C,EUN,t}\right) = a + \xi_{QC_C,CP_C} \cdot Log\left(\frac{CP_{C,EUN,t}}{CPI_{EUN,t}}\right) \tag{36}$$
$$+\xi_{QC_C,GDPI} \cdot Log\left(GDPI_{EUN,t}\right) + trend + R_{C,EUN}$$

2.2.2 EU Ethanol and biodiesel production

The general biofuel module in Aglink-Cosimo represents the production of biofuels, the production and use of by-products, and biofuel use for transport (von Lampe, 2008). Furthermore, it considers foreign net trade, which is balanced by world equilibrium prices at the global level. Separate markets are represented for the two major types of biofuels: ethanol and biodiesel. For both types, the supply side of the model structure distinguishes between first-generation biofuels from agricultural commodities (i.e. cereals and sugar crops, in the case of ethanol, and vegetable oils, in the case of biodiesel), second-generation biofuels from dedicated biomass production (i.e. cellulose-based ethanol from crops, such as fast-growing wood or grasses, and synthetic biodiesel from biomass crops), second-generation biofuels from crop residues (in particular from straw), and other biofuels (including fuels derived from, for example, algae, municipal waste, used frying oil, etc.) (see table 4). Among these types, first-generation biofuels from agricultural commodities are fully endogenous in the model, while production of second-generation and other biofuels is exogenous.

Table 4: Breakdown of the biofuel aggregates in Aglink-Cosimo		
	Biofuel type	
Production type	**Ethanol**	**Biodiesel**
First generation biofuels from crops	Additional demand for cereals, sugar crops Animal by-products (DDGs)	Additional demand of vegetable oils
Second generation biofuels from ligno-cellulosic material	Alternative use of crop land	
Second generation biofuels from crop residues	Increase in crop revenues from cereal production	
Other biofuels	Exogenous	

Production of biofuels is generally represented by the production capacity and the capacity use rate. Production capacity is modelled as a function of the net revenues from biofuel production, i.e. the difference between the output value (biofuel price and any subsidies directly linked to biofuel production) and the production costs per unit of biofuels (net of the value of by-products). Capacity generally responds to these net revenues with several time lags, given the time required to plan and construct new facilities. The capacity use rate, in contrast, depends on net revenues not considering capital fixed costs, and responds to market signals without lags. Generally, biofuel production is modelled separately for individual feedstocks and added up for the total production. Several feedstocks are used for each type of biofuel in a given country.

By-products from biofuel production form an integral element of the cost–benefit ratio. At the same time, some of these by-products return into the agricultural production process, in particular dried distiller's grains, a by-product of grain-based ethanol production that deserves special attention.

The demand for ethanol is generally split up into three components:

- An additive component (QC..ADD) in which ethanol replaces other (chemical) additives in the blend with gasoline; in this case ethanol and gasoline are complements.

- A low-level blend (LBLD) component in which the lower energy content of ethanol compared with gasoline is offset by other superior qualities, e.g. higher oxygen content and octane level. In this case, there are two options: (i) if the blend is mandatory, ethanol and gasoline are considered complements; and (ii) if there is no mandatory target, ethanol and gasoline are considered substitutes.

- A high-level blend (HBLD) – ethanol as a neat fuel consumed by specifically modified vehicles. In this case, ethanol and gasoline are substitutes.

These three demand components are explicitly taken into account in estimating the ethanol demand, always considering the price ratio between ethanol and fossil gasoline as the driving variable.

Biodiesel use is modelled in a similar way in the EU, as a simple equation with the price ratio between biodiesel and fossil diesel. Potential mandates are taken into account in other countries.

With the exception of the EU and the USA, ethanol and biodiesel markets are cleared by a net trade position residual from domestic supply and demand, with the domestic prices for biofuels depending on their world prices, taking into account import tariffs when a country is in a net import situation. In the USA and the EU, the clearing mechanism is the same as for any other Aglink commodity.

The change in biofuel production capacity is modelled as the maximum of 20 % ($1-\xi_{QPC..VL,DSTR}$) of the previous year's figure ($QPC..C_{C,EUN,T-1}$) for ethanol and 70 % for biodiesel or the previous year's figure plus returns over investment: producer price ($PP_{C,EUN,t-i}$), direct payments ($DP..C_{c,EUN,t-i}$) and net production cost ($NC..C_{c,EUN,t-i}$) in real terms, as returns are deflated by the GDP deflator ($GDPD_{EUN,t-i}$). In general, there is an 18-month time lag to set up a biofuel plant but, as this is a long-term investment, the expected returns for ethanol are defined over a four-year period in the model. However, only a two-year lag is used for biodiesel. It is assumed that biofuel producers are aware of policy changes and take them into account immediately:

$$Log\left(QPC..C_{C,EUN,t}\right) =$$

$$max\begin{pmatrix} \left(QPC..C_{C,EUN,t-1} \cdot \left(1-\xi_{QPC..C,DSTR}\right)\right), \\ QPC..C_{C,EUN,t-1} + c \\ +\sum_{i=0}^{n} \xi_{QPC..C,PP_{C,t-i}} \cdot \frac{\left(PP_{C,EUN,t-i}+DP..C_{C,EUN,t-i}-NC..C_{C,EUN,t-i}\right)}{GDPD_{EUN,t-i}} \end{pmatrix}$$

$$+R_{QPC..C_{C,EUN}} \tag{37}$$

Net costs are the sum of variable net costs ($VNC..C_{C,EUN,t}$) and fixed costs ($FC..C_{C,EUN,t}$), where fixed costs depend on the GDP deflator ($GDPD_{EUN,t}$) and the other exogenous costs ($NC..C..OC_{C,EUN,t}$):

$$Log\left(FC..C_{C,EUN,t}\right) = \ c + \xi_{FC..C,NC..C..OC} \cdot log\left(\frac{\left(NC..C..OC_{C,EUN,t} \cdot GDPD_{EUN,t}\right)}{GDPD_{EUN,t-1}}\right)$$
$$+R_{FC..C_{C,EUN}} \tag{38}$$

Variable net costs are a function of feedstock prices multiplied by their biofuel conversion rate , the cost coming from fossil fuel , the world oil prices and the euro/US dollar exchange rate :

$$VNC..C_{C,EUN,t} = BF..C..CONV_{C,EUN} \cdot PP_{C,EUN,t}$$
$$+ NC..C..OILC_{C,EUN} + NC..C..OIL \cdot XP..EUN_{WLD,OIL,t} \cdot XR_{EUN,t}$$
$$+ NC..C..OC_{C,EUN,t} \tag{39}$$

Capacity use rates are modelled as a function of variable net costs ($VNC..C_{EUN,C}$), biofuel prices ($PP_{C,EUN,t}$), and direct payments ($DP..VL_{C,EUN}$) with lower ($QPRL..C_{C,EUN,t}$) and upper ($QPRU..C_{C,EUN,t}$) limits that evolve on a logistic function at constant rates $C..LOGA_{EUN,C}$ and $C..LOGB_{EUN,C}$:

$$QPR..C_{C,EUN,t} = \left(QPRL..C_{C,EUN,t} + \frac{\left(QPRU..C_{C,EUN,t} - QPRL..C_{C,EUN,t}\right)}{\left(1 + C..LOGA_{EUN,C} \cdot e^{\frac{C..LOGB_{EUN,C}*VNC..C_{EUN,C}}{PP_{C,EUN}+DP..VL_{C,EUN}}}\right)}\right)$$
$$\cdot R_{QPR..C} \tag{40}$$

Second-generation ethanol and biodiesel are assumed to be exogenous ($QP..SEC_{C,EUN,t}$). Ethanol from biomass not produced in agricultural systems ($QP..NAGR_{ET,EUN,t}$) (e.g. from forestry, household waste, algae, etc.) is also assumed to be exogenous. Biodiesel from agricultural residuals ($QP..RES_{BD,EUN,t}$), e.g. waste oils, is modelled as an exogenous variable but contributes to the share ($QP..RESSHR_{BD,EUN,t}$) of first-generation biodiesel production ($QPC..VL_{BD,EUN,t} \cdot QPR..VL_{BD,EUN,t}$) such that:

$$QP..RES_{BD,EUN,t} = QP..RESSHR_{BD,EUN,t} \cdot QPC..VL_{BD,EUN,t} \cdot QPR..VL_{BD,EUN,t} \tag{41}$$

Total ethanol and biodiesel production is the sum of the individual quantities of biofuel by type of feedstock, second-generation and residuals or non-agricultural sources as follows:

$$QP_{BD,EUN,t} = QP..VL_{BD,EUN,t} + QP..SEC_{BD,EUN,t} + QP..RES_{BD,EUN,t} \tag{42}$$

and

$$QPET,EUN,t = QP..WT_{ET,EUN,t} + QP..CG_{ET,EUN,t} + QP..SBE_{ET,EUN,t}$$
$$+ QP..SEC_{ET,EUN,t} + QP..NAGR_{ET,EUN,t} \tag{43}$$

First-generation biofuels are a function of capacity use rate and production capacity:

$$QP..C_{C,EUN,t} = QP..CSHR_{c,EUN,t} \cdot QPC..C_{c,EUN,t} \cdot QPR..C_{c,EUN,t} \tag{44}$$

Domestic market clearing prices are modelled as in any other commodity markets, but not including stock changes:

$$O = QP_{c,EUN,t} - QC_{c,EUN,t} + IM_{C,EUN,t} - EX_{C,eun,t} \tag{45}$$

In modelling the share of coarse grains in ethanol production ($QP..CGSHR_{ET,EUN,t}$), competition between coarse grains and wheat feedstock is achieved by comparing their production variable net cost such that:

$$\begin{aligned} Log\left(QP..CGSHR_{ET,EUN,t}\right) = c + \xi_{QP..CGSHR,VNC..CG} \cdot log\left(\frac{VNC..CG_{ET,EUN,t}}{VNC..WT_{ET,EUN,t}}\right) \\ +log\left(R_{QP..CGSHR}\right) \end{aligned} \tag{46}$$

2.2.3 EU ethanol and biodiesel consumption

Consumption of ethanol and biodiesel are modelled differently.

As in the general model, ethanol consumption in the EU is assumed to come from three sources: additives (i.e. only ethanol), low-level blends and high-level blends.

Ethanol consumption as an additive ($QC..ADD_{ET,EUN,t}$) depends on gasoline consumption ($QC_{GAS,EUN,t}$) and its share as an additive ($QCS..ADD_{ET,EUN,t}$):

$$QC..ADD_{ET,EUN,t} = QCS..ADD_{ET,EUN,t} \cdot QC_{GAS,EUN,t}\, QC_{GAS,EUN,t} / \xi_{ERAT..GAS} \tag{47}$$

Consumption of ethanol in low-level blends ($QC..LBLD_{C,EUN,t}$) reacts to biofuel consumption in the previous year ($QC..BF_{C,EUN,t-1}$) discounting consumption for high-level blends, which is assumed to be exogenous ($QC..HBLD_{c1,EUN,t-1}$) and consumption as additives, the consumer price of the ethanol ($CP_{c1,EUN,t-1}$), the consumer price of the fossil fuel ($CP_{c2,EUN,T-1}$), the total weighted GDP index for the EU-28 (($GDPI_{E15,t}$ + $GDPI_{NMS,t}$) / ($POP_{E15,t}$ + $POP_{NMS,t}$)) Since the elasticity of the ethanol price is exactly the reverse sign of the elasticity of the fossil fuel price, the use of price in nominal terms is not a problem, because this specification is equivalent to a price ratio between the two substitutes:

$$\begin{aligned} Log\left(QC..LBLD_{c,EUN,t}\right) &= c \\ &+\xi_{QC..LBLD,LAG} \cdot Log\begin{pmatrix} QC..BF_{c,EUN,t-1} - QC..HBLD_{c1,EUN,t-1} \\ -QC..ADD_{c,EUN,t-1} \end{pmatrix} \\ &+\xi_{QC..LBLD,CP_{c1}} \cdot Log\left(CP_{c1,EUN,t-1} * ERAT..C1_{C,WLD}\right) \\ &+\xi_{QC..LBLD,CP_{c2}} \cdot Log\left(CP_{c2,EUN,t-1}\right) \\ &+\xi_{QC..LBLD,GDPI} \cdot Log\left(\frac{GDPI_{E15,t}+GDPI_{NMS,t}}{POP_{E15,t}+POP_{NMS,t}}\right) \\ &+\xi_{QC..LBLD,POP} \cdot Log\left(POP_{E15,t} + POP_{NMS,t}\right) + Log\left(R_{QC..LBLD}\right) \end{aligned} \tag{48}$$

Ethanol consumption in blends ($QC..BLD_{c,EUN,t}$) is the sum of low- and high-level blends:

$$QC..BLD_{c,EUN,t} = QC..LBLD_{c,EUN,t} + QC..HBLD_{c,EUN,t} \tag{49}$$

Biodiesel consumption ($QC_{BD,EUN,t}$) is the maximum value between the blending consumption determined by market conditions ($QC..BLD_{BD,EUN,t}$) and the obligation ($QC..OBL_{,EUN,t}$):

$$QC_{BD,EUN,t} = max\,(QC..BLD_{BD,EUN,t}, QC..OBL_{BD,EUN,t}) \tag{50}$$

Ethanol fuel consumption ($QC..BF_{ET,EUN,t}$) is the maximum between the obligation ($QC..OBL_{ET,EUN,t}$) and blending plus additive consumption:

$$QC..BF_{ET,EUN,t} = max\begin{pmatrix} QC..ADD_{ET,EUN,t} \\ +QC..BLD_{ET,EUN,t}, QC..OBL_{ET,EUN,t} \cdot QC_{ET,EUN,t}/\xi_{ERAT..GAS} \end{pmatrix} \tag{51}$$

The difference between consumer ($CP_{c,EUN,t}$) and producer ($PP_{c,EUN,t}$) prices is explained by fuel taxes ($TAX_{c,EUN,t}$) and retail margins ($MAR_{c,EUN,t}$):

$$CP_{c,EUN,t} = PP_{c,EUN,t} + TAX_{c,EUN,t} + MAR_{c,EUN,t} \tag{52}$$

2.2.4 Dried distiller's grains

Production of dried distiller's grains ($QP_{DDG,EUN,t}$) depends on ethanol production from grains, in specific coarse grains (QT..CG$_{ET,EUN,t}$) and wheat ($QP..WT_{ET,EUN,t}$), and their conversion rates, $QP..CG..CONV_{DDG,EUN,t}$ and $QP..WT..CONV_{DDG,EUN,t}$, such that:

$$\begin{aligned} QP_{DDG,EUN,t} = {} & QP..WT..CONV_{DDG,EUN,t} \cdot 10 \cdot QP..WT_{ET,EUN,t} \\ & + QP..CG..CONV_{DDG,EUN,t} \cdot QP..CG_{ET,EUN,t} \cdot 10 \end{aligned} \tag{53}$$

The factor 10 is the conversion factor from hectolitres to thousand litres.

Tables 5 and 6 summarise the different conversion factors between biofuel feedstocks and biofuel production and the coefficients used to transform biofuel volumes in fuels:

Table 5: Biofuel conversion factors

	Ethanol	Biodiesel		Diesel	Gasoline
Coarse grains	0.23	–	Biodiesel	0.92	–
Sugar beet	0.97	–	Gasoline	0.89	–
Wheat	0.25	–	Ethanol	0.59	0.67
Vegetable oils	–	0.09		–	–

Table 6: Biofuel coefficients for volume conversion

	toe/t	toe/m3	t/m3
Ethanol	0.645	0.5016	0.778
Biodiesel	0.884	0.7882	0.892
Gasoline	1.027	0.764	
Diesel	1.027	0.86	

** toe: tonnes of oil equivalent*
Source: calculation based on Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

2.3 Structural characteristics of EU agricultural domestic demand

2.3.1 Characteristics and components of consumption

In a similar way to the area allocation system, the demand system in Aglink-Cosimo is symmetrical. However, it is not homogeneous of degree zero, because too many products are missing in the model.

Domestic demand is made up of six different components: biofuels, crushing, domestic feed, domestic food, high fructose corn syrup and other uses. Table 7 shows the type of usage by commodity within the EU. Note that the use of cotton is not split, as it is used only for fibre.

Table 7: Demand positions by commodity in Aglink-Cosimo

Commodity	Code	Biofuel demand	Crushing demand	Feed demand	Food demand	High-fructose corn syrup	Other uses
Barley	BA	×		×	×		×
Dried beans	BN			×			
Beet pulp	BP			×			
Butter	BT				×		
Beef and veal	BV				×		
Casein	CA				×		
Cereal bran	CEB			×			
Coarse grains	CG	×		×	×	×	×
Corn gluten feed	CGF			×			
Cheese	CH				×		
Coconut oil	CL	×			×		×
Coconut meal	CM			×			
Cottonseed	CSE		×		×		×
Cottonseed oil	CSL	×			×		×
Cottonseed meal	CSM			×			
Dried distiller's grains	DDG			×			
Eggs	EG				×		
Ethanol	ET						×
Fresh dairy products	FDP				×		
Fish from aquaculture	FHA				×		
Fish meal	FM			×			
Field peas	FP			×			
Groundnut oil	GL	×			×		×
Groundnut meal	GM			×			
Groundnuts	GN		×		×		×
High-fructose corn syrup	HFCS				×		
Palm kernel oil	KL	×			×		×
Palm kernel meal	KM			×			
Maize	MA	×		×	×	×	×
Meat bone meal	MBM			×			×
Milk	MK			×			×
Manioc	MN			×			

Commodity	Code	Biofuel demand	Crushing demand	Feed demand	Food demand	High-fructose corn syrup	Other uses
Molasses	MOL	×		×			×
Other cereals	OC	×		×	×		×
Oilseeds oil	OL	×			×		×
Oilseeds meal	OM			×			
Oilseeds	OS		×		×		×
Oats	OT			×	×		×
Pork	PK				×		
Palm oil	PL	×			×		×
Protein meal	PM			×			
Poultry	PT				×		
Rice	RI				×		
Rapeseed oil	RL	×			×		×
Rapeseed meal	RM			×			
Rapeseed	RP		×		×		×
Rye	RY	×		×	×		×
Soybean	SB		×		×		×
Sugar beet	SBE	×					
Sugar cane	SCA	×					
Sunflower seed	SF		×		×		×
Sunflower oil	SFL	×			×		×
Sunflower meal	SFM			×			
Sheep	SH				×		
Soybean oil	SL	×			×		×
Soybean meal	SM			×			
Skimmed milk powder	SMP			×	×		
Sugar	SU				×		
Sweetener	SW				×		
Vegetable oil	VL	×			×		×
Whole milk powder	WMP				×		
Wheat	WT	×		×	×		×
Durum wheat	WTD			×	×		×
Soft wheat	WTS	×		×	×		×
Whey protein	WYP			×			×

2.3.2 Consumption of arable crops

Domestic demand is modelled as the sum of the biofuel use ($BF_{c,r,t}$), crushing ($CR_{c,r,t}$), feed use ($FE_{c,r,t}$), food use ($FO_{c,r,t}$), high-fructose corn syrup use ($CR_{c,r,t}$) and other uses ($OU_{c,r,t}$) such that:

$$QC_{c,r,t} = BF_{c,r,t} + CR_{c,r,t} + FE_{c,r,t} + F0_{c,r,t} + HCFS_{c,r,t} + OU_{c,r,t} \quad (54)$$

In the EU, biofuel use ($BF_{c,EUN,t}$) of coarse grains, wheat and vegetable oil is a function of the quantity of biofuel produced from each commodity ($QP..C_{C1,EUN,t}$) and the exogenous conversion rate ($BF..C1..CONV_{c,EUN,t}$), such that:

$$BF_{c,EUN,t} = 10 \cdot QP..C_{C1,EUN,t} \cdot BF..C1..CONV_{c,EUN,t} \quad (55)$$

where $C1$ denotes either ethanol (for coarse grains and wheat) or biodiesel (for vegetable oil) and 10 is the conversion factor from hectolitres ($BF..C1..CONV_{c,EUN,t}$) to thousand litres ($BF_{c,EUN,t}$).

Biofuel use in the EU-15 and EU-N13 is calculated for individual crops by multiplying the biofuel use at the EU level for the aggregated commodities ($BF_{C1,EUN,t}$) by the exogenous share ($BF..SHR_{c,EUN,t}$):

$$BF_{c,r,t} = BF_{C1,EUN,t} \cdot BF..SHR_{c,EUN,t} \tag{56}$$

Crushing use ($CR_{c,r,t}$), concerns only oilseeds, and it is calculated as a function of the crushing margins ($CRMAR_{c,r,t}$) multiplied by their elasticity ($\xi_{CR_c,CRMAR_c}$) for sunflower seed, soybean and rapeseed in each individual equation. There is competition between those three oilseeds for the actual crushing capacity in the EU:

$$\begin{aligned} Log\left(CR_{c,r,t}\right) = c + \xi_{CR_{SF},CRMAR_{SF}} \cdot Log\left(\frac{CRMAR_{SF,r,t}}{GDPD_{r,t}}\right) \\ +\xi_{CR_{SB},CRMAR_{SB}} \cdot Log\left(\frac{CRMAR_{SB,r,t}}{GDPD_{r,t}}\right) \\ +\xi_{CR_{RP},CRMAR_{RP}} \cdot Log\left(\frac{CRMAR_{RP,r,t}}{GDPD_{r,t}}\right) + trend + R_{CR,r} \end{aligned} \tag{57}$$

Food use for wheat, coarse grains, oilseeds, vegetable oil and rice is modelled as a function of consumer prices ($CP_{c,r,t}$), the consumer price index ($CPI_{r,t}$), the GDP index and the population ($POP_{r,t}$) such that:

$$\begin{aligned} Log\left(FO_{c,r,t}\right) = c + \sum^{c} \xi_{FO_c,CP_c} \cdot Log\left(\frac{CP_{c,r,t}}{CPI_{r,t}}\right) + \sum^{c} \xi_{FO_c,DGPI} \cdot Log\left(\frac{GDPI_{r,t}}{POP_{r,t}}\right) \\ +POP_{r,t} + trend + R_{CR,r} \end{aligned} \tag{58}$$

For disaggregated commodities (c1), food use is calculated with a share ($FO..SHR_{c1,r,t}$) multiplied by the food use of the aggregated commodity, such that:

$$FO_{c1r,t} = FO_{c,r,t} \cdot FO..SHR_{c1,r,t} \tag{59}$$

In order for food use to be balanced and the shares to add up to 1, the share of the disaggregated commodity is modelled as a function of the relative prices of the commodity $c1$ and a reference crop $c2$:

$$FO..SHR_{c1,r,t} = c + \xi_{FO..SHR_{c1},PP_{c2}} \cdot Log\left(\frac{PP_{c1,r,t}}{PP_{c2,r,t}}\right) + R_{FO..SHR,r} \tag{60}$$

The reference commodities are maize for coarse grain, soft wheat for wheat, sunflower oils for vegetable oils. Oilseeds (rapeseed, soybean, sunflower seed and cottonseed) shares are exogenous.

The food use share for the reference crops is modelled as 1 minus the sum of the other shares.

Other uses are directly modelled as a function of the commodity price and the consumer price index. For the aggregated commodities, other use is the sum of the individual crops that belong to the same aggregate:

$$Log\left(OU_{c,r,t}\right) = c + \sum^{c} \xi_{OU_c,PP_c} \cdot Log\left(\frac{PP_{c,r,t}}{CPI_{r,t}}\right) + trend + R_{FO,r} \tag{61}$$

Use of crops for producing high-fructose corn syrup (HCFS) concerns only maize; it is calculated as a function of the quantity produced ($QP_{HCFS,r,t}$) divided by the processing conversion rate:

$$HCFS_{MA,r,t} = QP_{HCFS,r,t}/0.6 \tag{62}$$

2.3.3 Sugar

Sugar domestic demand ($QC_{SU,r,t} = FO_{SU,r,t}$) is represented as a function of the sweeteners food use ($FO_{SW,r,t}$) minus high-fructose corn syrup consumption, such that:

$$FO_{SU,r,t} = (FO_{SW,r,t} - QC_{HFCS,r,t}) \ / \ 0.92 \tag{63}$$

As in the case of aggregated arable crops, sweeteners food use is modelled based on the relative price of isoglucose (high-fructose corn syrup) and sugar.

Total consumption of molasses at the EU-28 level is the sum of three elements—feed, biofuel and other uses—all being endogenous to the system:

$$QC_{MOL,r,t} = c + \xi_{QC_{MOL},PP_{MOL}} \cdot Log\left(\frac{PP_{MOL,r,t}}{CPI_{r,t}}\right) + \xi_{QC_{MOL},GDPI} \cdot Log(GDPI_{r,t})$$
$$+trend + R_{QC,r} \tag{64}$$

Molasses feed use has a similar representation to aggregated arable crops. The linkage variable between feed use and domestic demand is the price ($PP_{MOL,r,t}$).

2.3.4 Livestock and dairy demand

Domestic demand for livestock products includes meats and dairy products. Regarding meats, poultry, beef and veal, pork and sheep and goat meat is included in food use. Concerning dairy products, casein, cheese, butter, fresh dairy products and whole milk powder are consumed as food in the model. Skimmed milk powder is used both for food and feed, and whey protein has feed and other uses.

Milk food demand is not included in the model, only demand for feed and other uses. Nevertheless, milk food use is implicitly considered through the fat and non-fat solid equations in dairy products.

Milk other use is calculated using the same equations as the other commodities. Milk feed demand is modelled as a function of the cow inventory of the previous year ($CI_{MK,r,t-1}$):

$$Log\ (FE_{MK,r,t}) = c + \sum^{c} \xi_{FEMK,CIMK} \cdot Log\ (CI_{MK,r,t-1}) + R_{FE,r} \tag{65}$$

2.3.5 Feed demand

The new feed demand system in Aglink-Cosimo was built in 2013–2014 and includes 15 elements (see Table 8) (Charlebois, 2013). With the aim of facilitating communication, understanding cross-price effects and facilitating the mapping of feed products to livestock categories, feed products were grouped into three categories depending on their protein level: low-protein feed (LPF), medium-protein feed (MPF) and high-protein feed (HPF). This is summarised in Table 8.

Table 8: Feed products in Aglink-Cosimo

Low-protein feed	Medium-protein feed	High-protein feed
Coarse grains	Corn gluten feed	Protein meal
Wheat	Dried distiller's grains	Meat and bone meal
Rice	Field peas	Fish meal
Cereal bran	Whey powder	Skimmed milk powder
Dried beet pulp		
Molasses		
Roots and tubers/manioc		

Feed demand ($FE_{c,r,t}$) is a function of meat production ($QP_{c,r,t}$) from ruminants (i.e. sheep, beef and veal), milk production, feed use by non-ruminants ($FE_{NR,r,t}$), feed use by aquaculture species ($FE_{FHA,r,t}$) and different commodity prices in the EU ($PP_{c,EUN,t}$) and their elasticities ($\xi_{FE_c,PP\,c,EUN}$):

$$Log\left(FE_{c,r,t}\right) = c + \sum^{c} \xi_{APF_{r,FE},QP_{r,c}} \cdot Log\left(QP_{c,r,t}\right) + \xi_{APF_{FE,r},FHA_{FE,r}} \cdot FE_{NR,r,t}$$
$$+\left(1 - \sum^{c} \xi_{APF_{r,FE},QP_{r,c}}\right) \cdot FE_{NR,r,t} + \sum^{c} \xi_{FE_c,PP_c} \cdot Log\left(\frac{PP_{c,r,t}}{GDPD_{r,t}}\right)$$
$$+trend + R_{CR,r} \tag{66}$$

where $\xi_{APF_{r,FE},QP_{r,c}}$ denotes the elasticity for the average protein feed (APF) with respect to meat production, $\xi_{APF_{r,FE},QP_{r,c}}$ denotes the elasticity for the APF with respect to aquaculture production (FHA), and $\xi_{FE_c,PP_{c,EUN}}$ the elasticity for commodity feed use (FE) with respect to the commodity price.

For disaggregated commodities, feed use is calculated with a share ($FE..SHR_{c1,r,t}$) multiplied by the feed use such that:

$$F_{Ec1,r,t} = FE_{c,r,t} \cdot FE..SHR_{c1,r,t} \tag{67}$$

The share of the disaggregated commodity ($c1$) is modelled as a function of the relative prices of the commodity $c1$ and a reference crop $c2$. The reference ensures that the shares add up to 1:

$$FE..SHR_{c1,r,t} = c + \xi_{FE..SHR_{c1},PP_{c2}} \cdot Log\left(\frac{PP_{c1,r,t}}{PP_{c2,r,t}}\right) + R_{FE..SHR,r} \tag{68}$$

The reference commodities ($c2$) are maize for coarse grains, soft wheat for wheat and soybean meal for protein meals. The shares for the reference commodities are calculated as 1 minus the sum of the share of the other commodities belonging to the same aggregate:

$$FE..SHR_{rc,r,t} = 1 - \sum_{c \neq cr}^{c} FE..SHR_{c,r,t} \tag{69}$$

For dried beans (BN), feed use and production are equal ($FE_{BN,t} = QP_{BN,r,t}$).

The average protein feed ($FE_{APF,r,t}$) is the aggregate of low-protein feed ($FE_{LPF,r,t}$), medium-protein feed ($FE_{MPF,r,t}$) and high-protein feed ($FE_{HPF,r,t}$) as follows:

$$FE_{APF,r,t} = FE_{LPF,r,t} + FE_{MPF,r,t} + FE_{HPF,r,t} \tag{70}$$

Low-, medium- and high-protein feed are the aggregation of the commodities belonging to every category by their protein content as follows:

$$FE_{LPF,r,t} = FE_{CG,r,t} + FE_{WT,r,t} + FE_{RI,r,t} + FE_{CEB,r,t} + FE_{BP,r,t} + FE_{MOL,r,t} + FE_{MN,r,t} \tag{71}$$

$$FE_{MPF,r,t} = FE_{CGF,r,t} + FE_{DDG,r,t} + FE_{FP,r,t} + FE_{WYP,r,t} \tag{72}$$

$$FE_{HPF,r,t} = FE_{PM,r,t} + FE_{MBM,r,t} + FE_{SMP,r,t} \tag{73}$$

Non-ruminant feed use ($FE_{MR,r,t}$) is modelled as function of pork, poultry and egg production, the exogenous feed conversion rate for pork, poultry and eggs and an exogenous adjusting factor for pork ($CY..EUN_{PK,USA,t}$) and poultry ($CY..EUN_{PT,USA,t}$):

$$FE_{NR,r,t} = \frac{QP_{PK,r,t}}{CY..EUN_{PK,USA,t}} \cdot FCR_{PK,r,t} + \frac{QP_{PT,r,t}}{CY..EUN_{PT,USA,t}} \cdot FCR_{PT,r,t} + QP_{PT,r,t} \cdot FCR_{PT,r,t} \tag{74}$$

Ruminant feed requirements ($FE_{RU,r,t}$) are modelled as the balance among the total feed requirements ($FE_{APF,r,t}$) minus non-ruminant and aquaculture feed requirements, such that:

$$FE_{RU,r,t} = FE_{APF,r,t} - FE_{NR,r,t} - FE_{FHA,r,t} \quad (75)$$

The feed cost index ($FECI_{c,r,t}$) is a weighted average price of feed used for animal production. Two types of feed cost index are written in the model, one for ruminants ($FECI_{RU,r,t}$) and another for non-ruminants ($FECI_{NR,r,t}$). Both indices are equal to the average protein feed price ($PP_{AVF,r,t}$), which is a weighted price of the feed with different protein levels such that:

$$FECI_{C,r,t} = PP_{AVF,r,t} = \frac{FE_{LPF,r,t} \cdot PP_{LPF,r,t} + FE_{MPF,r,t} \cdot PP_{MPF,r,t} + FE_{HPF,r,t} \cdot PP_{HPF,r,t}}{FE_{APF,r,t}} \quad (76)$$

where $FE_{LPF,r,t}$, $FE_{MPF,r,t}$ and $FE_{HPF,r,t}$ denote the feed amount with low-protein feed, medium-protein feed and high-protein feed, respectively. The two types of feed cost index were kept in the model, even if the value is the same simply to give flexibility in the future in terms of introducing a specific link between type of feed and type of animal production.

The quantity consumed is only one element of a feed demand system. The other important one is animal requirements. Livestock production is fairly well represented in Aglink, with bovine, ovine and porcine meat, poultry, eggs and milk. But knowing the production from these animals is not sufficient; a feed conversion ratio ($FCR_{c,r,t}$) is also needed. The available information on feed conversion ratio is far from being complete and consistent over time, or between countries and between species. In the case of ruminants (beef and veal, sheep and milk), the exact definition of feed conversion ratio also needs to be considered. In Aglink-Cosimo a feed conversion ratio of concentrated feeds, i.e. the 15 elements identified earlier, is considered. With this in mind, the assumption of a fixed feed conversion ratio over time is particularly problematic, as there are important alternatives to these concentrated feeds in many of the model components, for instance fodder feeds (i.e. hay, pasture and maize silage). Therefore, a constant feed conversion ratio for ruminants cannot be assumed. For non-ruminants in most developed countries, a maximum feed conversion ratio has probably already been obtained, and for that reason can be kept exogenous over the outlook period. The feed conversion ratio for non-ruminants is therefore exogenous to the model and is disaggregated for pork, eggs and poultry. Concerning ruminants, the feed conversion ratio ($FCR_{RU,r,t}$) depends on beef and veal, sheep and milk production, and feed use in ruminants ($FE_{RU,r,t}$) as follows:

$$FCR_{RU,\boldsymbol{r},\boldsymbol{t}} = \frac{FE_{RU,\boldsymbol{r},\boldsymbol{t}}}{(QP_{BV,\boldsymbol{r},\boldsymbol{t}}/0.6+QP_{SH,r,t}/0.5/2+QP_{MK,\boldsymbol{r},\boldsymbol{t}}/4.8)} \quad (77)$$

The feed conversion ratios for beef and veal ($FCR_{BV,r,t}$), sheep ($FCR_{SH,r,t}$) and milk ($FCR_{MK,r,t}$) are modelled as functions of the $FCR_{RU,r,t}$ in the following way:

$$FCR_{BV,r,t} = FCR_{RU,r,t} \quad (78)$$

$$FCR_{SH,r,t} = FCR_{RU,r,t} / 2 \quad (79)$$

$$FCR_{MK,r,t} = FCR_{RU,r,t} / 4.8 \quad (80)$$

Production is converted to live weight, as feed conversion ratios are typically expressed on a live weight basis. The advantage of being able to calculate a residual variable from all the concentrated feeds and animal production is that inconsistencies between feed consumption and animal production outlook projections can be detected with only one variable.

2.4 Trade

2.4.1 Imports

For the EU module, imports ($IM_{c,r,t}$) are modelled only at the EU-28 level. The competiveness of domestic markets is accounted for by means of the relative price between the domestic price ($PP_{c,r,t}$). and the import price ($IMP_{c,r,t}$). Furthermore, import prices are potentially corrected by an advalorem import tariff ($TAVI_{c,r,t}$). Therefore, import tariffs have a negative impact on imports:

$$IM_{c,r,t} = c + \xi_{IM_C,PP_C} \cdot Log\left(\frac{PP_{c,r,t}}{IMP_{c,r,t} \cdot ((1+TAVI_{c,r,t})/100)}\right) + R_{IM} \quad (81)$$

Ad-valorem import tariffs are endogenous to the model. They depend on advalorem inquota tariffs ($TAV..IQS_{c,r,t}$), advalorem outofquota tariffs ($TAV..OQS_{c,r,t}$), specific inquota tariffs ($TSP..IQS_{c,r,t}$), specific outofquota tariffs ($TSP..OQS_{c,r,t}$), quota levels ($TRQ_{c,r,t}$), imports and import prices:

$$TAVI_{c,r,t} = TAV..IQS_{c,r,t} + c_1 \cdot \frac{TSP..IQS_{c,r,t}}{IMP_{c,r,t}} + \frac{e^{f(\cdot)}}{1+e^{\varphi(\cdot)}} \cdot g(\cdot) \tag{82}$$

where the function is denoted as :

$$f(\cdot) = \sigma \cdot Min(0,(IM_{c,r,t} - TRQ_{c,r,t}) / TRQ_{c,r,t}) \tag{83}$$

The maximum value the function $f(\cdot)$ can take is zero, in which case it has no impact on the ad-valorem duty. Negative values of $f(\cdot)$ have a negative effect on import tariffs.

The function $\varphi(\cdot)$, denoted as:

$$\varphi(\cdot) = -\frac{|IM_{c,r,t} - TRQ_{c,r,t}|}{TRQ_{c,r,t}} \cdot \sigma \tag{84}$$

can take only negative values, and as its value decreases (i.e. becomes more negative), the value of the ad-valorem tariff on imports increases.

The function $g(\cdot)$ denoted as:

$$g(\cdot) = \left(\frac{TAV..OQS_{c,r,t} + 100 \cdot TSP..OQS_{c,r,t}}{IMP_{c,r,t}} - \frac{TAV..IQS_{c,r,t} + 100 \cdot TSP..IQS_{c,r,t}}{IMP_{c,r,t}}\right) \tag{85}$$

specifies total in and outofquota tariffs expressed in advalorem equivalents plus the advalorem tariffs themselves. The tariff line references and tariffs used in the equation for year 2024 are shown in Tables 9.1 and 9.2.

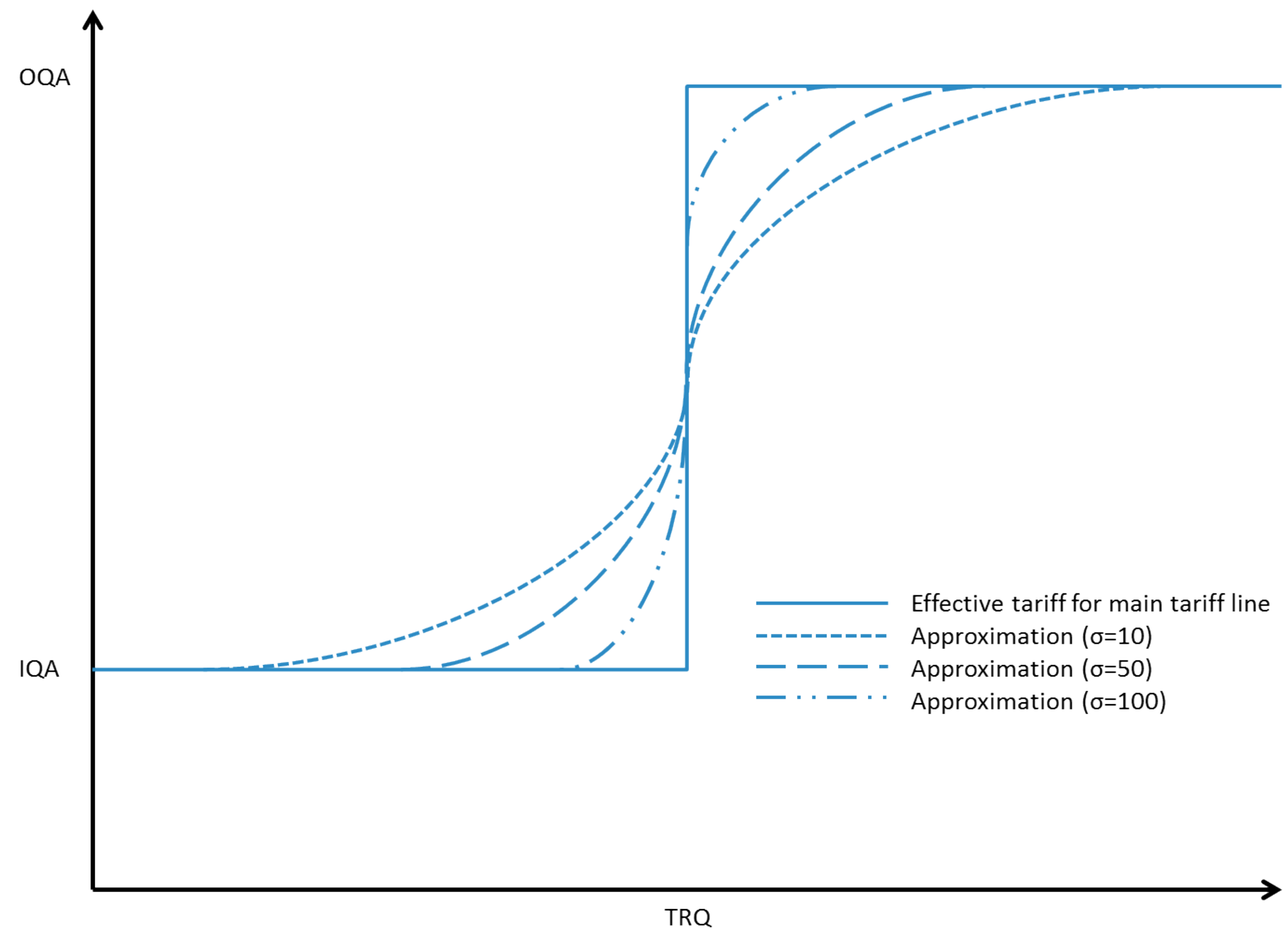
Table 9.1: Import tariff lines used as reference for the different sectors

Commodity group	Commodity	Tariff line reference	
		Combined nomenclature code	Label
Crops	Soft wheat	10 01 99 00	Common wheat, spelt and meslin grains
	Durum wheat	10 01 19 00	Durum wheat grains
	Barley	10 03 90 00	Barley grains
	Maize	10 05 90 00	Maize grains
	Rye	10 02 90 00	Rye grains
	Other cereals	10 07 90 00	Grain sorghum
	Rice	10 06 30	Semi-milled or wholly milled rice
	Sugar, white	17 01	
Dairy	Butter	0405 10 19	Butter
	Cheese	0406 90 21	Cheddar
Meat	Beef and veal	0201 30 00	Meat of bovine animals, fresh or chilled, boneless
	Sheep	0204 42 90	Meat of sheep and goats, frozen, other cuts with bone in
	Pork	0203 29 55	Meat of swine, frozen boneless
	Poultry	16 02 3219	Prepared or preserved chicken meat

Table 9.2: EU import tariffs used in the import equations for year 2024					
Commodity group	**Commodity**	**Ad-valorem in-quota tariff**	**Ad-valorem out-of-quota tariff**	**Specific in-quota tariff**	**Specific over-quota applied tariff**
Crops	Barley	–	–	16	93
	Rye	–	–	0	10
	Sugar	–	–	98	339
	Soft wheat	–	–	12	0
Dairy	Butter	–	–	700	1 896
	Cheese	–	–	210	1 671
Meat	Beef and veal	0	13	0	2 334
	Pork	–	–	208	869
	Poultry	15	0	0	1 024
	Sheep	0	13	0	2 122

The graphical approximation shown in Figure 2 should hold at any given point in time and for any particular tariff line. However, the aggregation of tariff lines in the model might cause such a relationship not to hold. The more tariff lines are included in any given commodity represented in the model, and the longer the time period represented by a particular observation, the more likely it is that imports at full duty will occur, even if the aggregate tariff-rate quota (TRQ) itself is under-filled, resulting in an effective tariff rate above the in-quota tariff with total imports below the tariff-rate quota level, and effective tariff rates below the over-quota tariff with total imports above the tariff-rate quota level. Therefore, approximating the above 'sword edge' relationship allows a representation of the tariff-rate quota that is simpler and more likely to represent the 'real' relationship between imports and the effective tariff rate. Because some particular parameters will define how close the approximation comes to the 'edged' original relationship, there is the problem of finding such parameters empirically, which may be seen as a disadvantage of such an approximation. However, as in the case of trade functions, the choice of using the 'exact' relationship in the model implies the choice of such a parameter being infinitely large—a choice that is correct in the case of individual tariff lines for a given point in time, but fairly arbitrary in the case of aggregation over products and time. In addition, the closer we push the model to this infinitely large number, the closer we are getting to mathematical discontinuity that will create a convergence problem in simulation. The parameter serves to approximate the function, as its value increases as it approaches the effective main tariff line; this is illustrated in Figure 2.

Figure 2: Non-linear approximations of tariff-rate quotas (TRQs)



The development of the advalorem import tariffs depends on the relationship between the tariff-rate quota and the imports, with three possible scenarios:

(1) When the imports are lower than the tariff-rate quota ($IM_{c,r,t} < TRQ_{c,r,t}$), then the share of the imports–quotas tariff difference is less than 1 (((IMc,r,t – TRQc,r,t / TRQc,r,t)<1). If the imports are very low, the logistic function $\frac{e^{f(\cdot)}}{1+e^{\varphi(\cdot)}}$ approximates zero; thus, the total in and outofquota tariffs in ad-valorem equivalents, denoted as the function $g(\cdot)$ above, has little impact on the $TAVI_{c,r,t}$.

(2) When the imports are equal to the tariff-rate quota ($IM_{c,r,t} = TRQ_{c,r,t}$), then the share of the imports–quotas tariff difference is zero (($IM_{c,r,t} - TRQ_{c,r,t} / TRQ_{c,r,t}$)=$0$). In this case, the logistic function $\frac{e^{f(\cdot)}}{1+e^{\varphi(\cdot)}}$ takes the value of 0.5.

(3) When the imports become large such that they surpass the tariff-rate quota ($IM_{c,r,t} > TRQ_{c,r,t}$), the share of the imports–quotas tariff difference is greater than 1, (($IM_{c,r,t} - TRQ_{c,r,t}$) / $TRQ_{c,r,t}$)>1). Under this scenario, as the imports grow, the logistic function $\frac{e^{f(\cdot)}}{1+e^{\varphi(\cdot)}}$ increases its value, such that the total in and outofquota tariffs in advalorem equivalents, denoted as the function $g(\cdot)$, has a larger effect on the value of $TAVI_{c,r,t}$, asymptotically converging towards the value of the outofquota tariff.

For the specific case of pork, sheep and beef and veal, imports are identified as meat imports ($IMM_{c,r,t}$). The equations remain the same with the same structure.

Sugar imports in the EU-28 ($IM_{SUr,t}$) are the aggregation of imports under special agreement ($IM..EBA_{SU,r,t}$) and others ($IM..OTH_{SUr,t}$); because imports under special agreement are limited by a quota, this value is entered into the calculation as a maximum of imports under preferential agreements:

$$IM_{SUr,t} = IM..OTH_{SU,r,t} + Min\,(IM..EBA_{SU,r,t},\ 7500) \qquad (86)$$

For the imports under special agreement, the advalorem import tariffs equals zero. For other imports, ad-valorem import tariffs calculations follows the same logic as the general and incorporates the tariff-rate quotas for imports under special agreement and others :

$$TAVI_{c,r,t} = \frac{e^{f'(\cdot)}}{1+e^{\varphi'(\cdot)}} \cdot \left(TAV..IQS_{SU,r,t} + \frac{100 \cdot TSP..IQS_{SU,r,t}}{IMP_{SUW,r,t}} + \frac{e^{f''(\cdot)}}{1+e^{\varphi''(\cdot)}} \cdot g'(\cdot) \right) \tag{87}$$

The logic behind this is to have two mechanisms that regulate the quota. The first one is governed by a logistic function $\frac{e^{f(\cdot)}}{1+e^{\varphi(\cdot)}}$ and reacts on the basis of the difference between other imports and the gap in the tariff quota for special agreements and others, as denoted in functions $f'(\cdot)$ and $\varphi'(\cdot)$:

$$f'(\cdot) = min\left(0, \frac{IM..OTH_{SU,r,t} - (TRQ..BAL_{SU,r,t} + TRQ..OTH_{SU,r,t})}{(TRQ..BAL_{SU,r,t} + TRQ..OTH_{SU,r,t})} \cdot \sigma\right) \tag{88}$$

$$\varphi'(\cdot) = -\frac{|IM..OTH_{SU,r,t} - (TRQ..BAL_{SU,r,t} + TRQ..OTH_{SU,r,t})|}{(TRQ..BAL_{SU,r,t} + TRQ..OTH_{SU,r,t})} \cdot \sigma \tag{89}$$

The second mechanism governing the quota is based on the difference between other imports and the general tariff-rate quota. As denoted in functions $f''(\cdot)$ and $\varphi''(\cdot)$:

$$f''(\cdot) = min\left(0, \frac{IM..OTH_{SU,r,t} - TRQ_{SU,r,t}}{TRQ_{SU,r,t}} \cdot \sigma\right) \tag{90}$$

$$\varphi''(\cdot) = -\frac{|IM..OTH_{SU,r,t} - TRQ_{SU,r,t}|}{TRQ_{SU,r,t}} \cdot \sigma \tag{91}$$

Finally, the level of the advalorem import tariffs is set up accounting for in and outofquota advalorem tariffs and in and outofquota specific tariffs, as denoted in function $g'(\cdot)$:

$$g'(\cdot) = \left(TAV..OQS_{SU,r,t} + 100 \cdot \frac{TSP..OQS_{SU,r,t}}{IMP_{SUW,r,t}} - TAV..IQS_{SU,r,t} + 100 \cdot \frac{TSP..IQS_{SU,r,t}}{IMP_{SUW,r,t}} \right) \tag{92}$$

After the elimination of production quotas in 2017, as a result of the reform of the CAP, the production of sugar beet will probably increase. Following this growth in the domestic supply, imports from countries under special agreements and others will potentially decrease.

2.4.2 Exports

Exports in the EU ($EX_{c,r,t}$) are the aggregation of subsidised ($EX..SUB_{c,r,t}$) and unsubsidised exports ($EX..UNS_{c,r,t}$):

$$EX_{c,r,t} = EX..SUB_{c,r,t} + EX..UNS_{c,r,t} \tag{93}$$

Unsubsidised exports are modelled in a similar way to imports; those are a function of the domestic price, the export price and the export tax, which is exogenous and equal to zero in most countries except Argentina:

$$EX_{c,r,t} = c + \xi_{EX_C, PP_C} \cdot Log\left(\frac{PP_{c,r,t}}{EXP_{c,r,t} \cdot ((1 + TAVE_{c,r,t})/100)}\right) + R_{EX} \tag{94}$$

Concerning the subsidised exports, the relationship between the domestic price and the support price ($SPE_{c,r,t}$) determines the level of the exports. For this, three different regimes are considered:

(1) Subsidised exports equal zero if the domestic price is greater than the upper bound for the support price ($SUBUBc,r,t$):

$$For\ PP_{c,r,t} \geq SUBUB_{c,r,t} \cdot SPE_{c,r,t}\ then\ EX..SUB_{c,r,t} = 0 \tag{95}$$

(2) Subsided exports are limited by the upper ($SUBUB_{c,r,t}$) and lower ($SUBLB_{c,r,t}$) bounds for the support price:

$$For\ PP_{c,r,t} < SUBUB_{c,r,t} \cdot SPE_{c,r,t}\ and\ PP_{c,r,t} > SUBLB_{c,r,t} \cdot SPE_{c,r,t}$$

$$then\ EX..SUB_{c,r,t} = \frac{EX..WT0FY_{c,r,t}(SUBUB_{c,r,t} \cdot SPE_{c,r,t} - PP_{c,r,t})}{SUBUB_{c,r,t} \cdot SPE_{c,r,t} - SUBLB_{c,r,t} \cdot SPE_{c,r,t}} \quad (96)$$

(3) Subsidised exports are equal to the limit set by the World Trade Organization (WTO) limit for subsidised exports if the domestic price is lower than the lower bound for the support price

$$For\ PPc,r,t \leq SUBLB_{c,r,t} \cdot SPE_{c,r,t}$$

$$then\ EX..SUB_{c,r,t} = EX..WT0FY_{c,r,t} \quad (97)$$

For barley and skimmed milk power, instead of using the WTO limit, the calculation is done using the lower limit ($SUBLB_{c,r,t}$). The reason is that both products are still subject to support measures.

Beef and veal exports ($EXM_{BV,r,t}$) are the aggregate of unsubsidised ($EXM..UNS_{BV,r,t}$) and subsidised ($EXM..SUB_{BV,r,t}$) exports. For unsubsidised beef and veal exports, the calculation is the same as the general one. For subsidised exports, the calculation is based on the reference price ($RP_{BV,r,t}$) which is exogenous, such that two scenarios are possible:

(1) If the domestic price is greater than the reference price, then subsidised exports are equal to zero:

$$For\ PP_{BV,r,t} > RP_{BV,r,t}\ then\ EXM...SUB_{BV,r,t} = 0 \quad (98)$$

(2) If the domestic price is lower or equal to the reference price, the export subsidies are times the price gap. The value σ, as shown in Figure 2, determines the smoothness of the non-linear approximation:

$$For\ PP_{BV,r,t} \leq RP_{BV,r,t}\ then\ EXM...SUB_{BV,r,t} = (RP_{BV,r,t} - PP_{BV,r,t}) \cdot \sigma \quad (99)$$

Pork exports ($EXM_{PK,r,t}$) are the aggregate of subsidised exports ($EXM..SUB_{PK,r,t}$), exports to the Pacific region ($EXM..PAC_{PK,r,t}$), exports to the Atlantic region ($EXM..ATL_{PK,r,t}$) and exports to China ($EXM..CHN_{PK,r,t}$).

Subsidised exports are equal to zero if the domestic price is greater than the reference price, otherwise they are modelled as:

$$EXM..SUBPK,r,t = min\ (((RP_{PK,r,t} - PP_{PK,r,t}) \cdot 3), EXM..SUBLIM_{PK,r,t}) \quad (100)$$

where the variable $EXM..SUBLIM_{PK,r,t}$ denotes an upper limit.

For exports to the Pacific and Atlantic region, the calculation is done using the standard export equation. Nonetheless, the reference prices used are those of the Atlantic or the Pacific regions:

$$EX_{PK,r,t} = c + \xi_{EX_{PK},PP_C} \cdot Log\left(\frac{PP_{c,r,t}}{(XP_{c,r,t} \cdot XR_{r,t}) \cdot ((1+TAVE_{c,r,t})/100)}\right) + R_{EX} \quad (101)$$

Exports to China ($EXM..XCHN_{PK,EUN,t}$) are calculated by multiplying the total Chinese pork imports ($IM..EUN_{PK,CH,t}$) by the share coming from the EU-28 ($SHREUN..EUN_{PK,CH,t}$).

Sugar exports ($EX_{SU,r,t}$) are the aggregate of raw sugar ($EX_{SUR,r,t}$) and white sugar ($EX_{SUW,r,t}$) exports, the first of which is exogenous. White sugar exports are the aggregate of subsidised and unsubsidised exports. Unsubsidised exports are modelled as a function of the competition between the domestic and the world markets without any ad-valorem tax. Subsidised exports are set to zero when the EU-28 sugar quota, the aggregate of the EU-15 and the EU-N13, equals zero, otherwise it is set to the lower limit for white sugar subsidised exports ($EX..SUBLIM_{SUW,r,t}$ = 1375), divided by 0.92, the processing factor between raw sugar and white sugar.

The elimination of sugar quotas in 2017 is accounted for in the model. Therefore, from that year onwards, subsidised exports are equal to zero and exports are determined in a competitive market (i.e. there is interplay between domestic and world prices).

2.4.3 Net trade

Net trade is simply modelled as the difference between exports and imports:

$$NT_{c,r,t} = EX_{c,r,t} - IM_{c,r,t} \quad (102)$$

2.5 EU Stocks

Stocks are modelled only at the EU-28 level. In the case of arable crops, stocks ($ST_{c,r,t}$) are the aggregate of private stocks ($PRST_{c,r,t}$) and intervention stocks ($IST_{c,r,t}$), the latter being exogenous:

$$ST_{c,r,t} = PRST_{c,r,t} + IST_{c,r,t} \quad (103)$$

Private stocks follow a transaction motive, captured by the product available over the current year, and a speculative motive, captured by the price in the current period divided by the average of the last three years:

$$\begin{aligned} PRST_{c,r,t} &= c + \sum_{i=-2}^{0} \left(\xi_{PRST_C,QP_C} \cdot Log\left(QP_{c,r,t-i} + PRST_{c,r,t-i-1}\right)\right) \\ &\quad + \xi_{PRST_c,PP_c} \cdot Log\left(3 \cdot \frac{PP_{c,r,t}}{PP_{c,r,t-1} + PP_{c,r,t-2} + PP_{c,r,t-3}}\right) + trend + R_{PRST,c,r} \end{aligned} \quad (104)$$

For meat products, there are no private stocks as such. Beef and veal, and pork stocks, are modelled using the same equation structure as for private stocks for crops. Poultry and sheep meat stocks are exogenous.

Biofuel stocks are not modelled.

For dairy products, instead of stocks, the variations in stocks ($VST_{c,r,t}$) are calculated as difference between the intervention stock for the current and previous year plus ($IST_{c,r,t} - IST_{c,r,t-1}$). The variation in private stocks ($VST..PRST_{c,r,t}$) is exogenous to the model:

$$VST_{c,r,t} = IST_{c,r,t} - IST_{c,r,t-1} + VST..PRST_{c,r,t} \quad (105)$$

Sugar stocks are modelled as an aggregate of intervention stocks, private stocks and carryforward stocks ($ST..CF_{c,r,t}$). Intervention stocks depend on the sugar levy ($LEVY_{SU,r,t}$) and the sugar support price ($SP_{SUW,r,t}$) which are exogenous to the model. If the domestic price for white sugar is lower than the difference between the support price and the sugar levy ($PP_{SUW,r,t} < SP_{SUW,r,t} - LEVY_{SU,r,t}$), then the intervention stocks are modelled as:

$$IST_{c,r,t} = (SP_{SUW,r,t} - LEVY_{SUW,r,t} - PP_{SUW,r,t}) \cdot 100 \quad (106)$$

Sugar private stocks are modelled as a function of production, private stocks in the previous year and price in the current period divided by the average of the last three years (i.e. a speculative motive):

$$\begin{aligned} PRST_{SU,r,t} &= c + \left(\xi_{PRST_{SU},QP_{SU}} \cdot Log\left(QP_{SU,r,t} + PRST_{SU,r,t-1}\right)\right) \\ &\quad + \xi_{PRST_{SU},PP_{SUW}} \cdot Log\left(3 \cdot \frac{PP_{SUW,r,t}}{PP_{SUW,r,t-1} + PP_{SUW,r,t-2} + PP_{SUW,r,t-3}}\right) \\ &\quad + trend + R_{PRST,SU,r} \end{aligned} \quad (107)$$

Carryforward stocks are set to zero once sugar quotas are eliminated. Before that, they are calculated as the sum of stocks of the previous year, production, quota, subsidised exports and quota change, where the quota change also depends on the carryforward stocks of year $t - 1$:

$$ST..CF_{SU,r,t} = max\left(0, \left(\begin{matrix} ST..CF_{SU,EUN,t-1} + QP_{SU,EUN,t} - QT_{SU,E15,t} \\ -QT_{SU,NMS,t} - EX..SUB_{SUW,EUN,t} - QT..CHG_{SU,EUN,t} \end{matrix}\right)\right) \quad (108)$$

2.6 Prices

2.6.1 Producer prices: arable crops and meat

Producer prices ($PP_{c,EUN,t}$) in domestic markets are modelled as closing market variables, thus ensuring a market balance including production, consumption, imports, exports and stocks. The general form of the equation is:

$$PP_{c,EUN,t}: 0 = QP_{c,EUN,t} + ST_{c,EUN,t-1} + IM_{c,EUN,t}$$
$$-QC_{c,EUN,t} - ST_{c,EUN,t} - EX_{c,EUN,t} \tag{109}$$

In order to reach market clearance, prices are adjusted. This is possible because the variables included in the clearing equation are functions of the producer prices.

The previous equation holds for most of the disaggregated commodities in arable crops, dairy products and meat.

For aggregated commodities such as coarse grains, oilseeds, vegetable oils and protein meals, producer prices are calculated as a weighted average, accounting for the production and price of each component of the aggregate in the following form:

$$PP_{c1,EUN,t} = \frac{\sum_c PP_{c,EUN,t} \cdot QP_{c,EUN,t}}{\sum_c QP_{c,EUN,t}} \tag{110}$$

In the specific case of high-, medium- and low-protein feed, products are modelled as a weighted average of individual prices of each component and feed use such that:

$$PP_{c1,EUN,t} = \frac{\sum_c PP_{c,EUN,t} \cdot FE_{c,EUN,t}}{\sum_c FE_{c,EUN,t}} \tag{111}$$

2.6.2 Producer prices: milk and dairy products

Milk prices in the EU28 are calculated as a weighted average of the milk price in the EU-15 and EU-N13 such that:

$$PP_{MK,EUN,t} = \frac{PP_{MK,E15,t} \cdot QP_{MK,E15,t} + PP_{MK,NMS,t} \cdot QP_{MK,NMS,t}}{QP_{MK.E15.t} + QP_{MK.NMS.t}} \tag{112}$$

Milk prices in the EU-15 and EU-N13 are modelled as functions of the fat ($FAT_{MK,r,t}$) and non-fat solids ($NFS_{MK,r,t}$) content of the milk. Prices for fat ($PP..FAT_{MK,r,t}$) and non-fat ($PP..NFS_{MK,r,t}$) contents and the margin ($MAR_{MK,r,t}$) are exogenous. Furthermore, a residual variable is added to the equation to allow for some flexibility in the adjustment of the balance of fat and non-fat solids:

$$PP_{MK,r,t} = \frac{PP..FAT_{MK,r,t} \cdot FAT_{MK,r,t} + PP..NFS_{MK,r,t} \cdot NFS_{MK,r,t}}{MAR_{MK,r,t}} \cdot R_{PP,r,c} \tag{113}$$

Prices for fat and non-fat solids are modelled as clearing equations for the fat and non-fat solids balances. The balance accounts for two main elements: (1) non-farm uses , e.g. compound feed use; and (2) dairy production, which includes the following commodities: fresh dairy products (FDP), butter (BT), cheese (CH), skimmed milk powder (SMP), whole milk powder (WMP), casein (CA), whey protein (WYP), and other fat products (OFP) for the fat solids and other non-fat products (ONP) for non-fat solids:

$$PP..FAT_{MK,r,t} : 0 = (QP_{MK,r,t} - FU_{MK,r,t}) * FAT_{MK,r,t} + QP_{FDP,r,t} \cdot FAT_{FDP,r,t}$$
$$+ QP_{BT,r,t} \cdot FAT_{BT,r,t} + QP_{CH,r,t} \cdot FAT_{CH,r,t} + QP_{SMP,r,t} \cdot FAT_{SMP,r,t}$$
$$+ QP_{WMP,r,t} \cdot FAT_{WMP,r,t} + QP_{CA,r,t} \cdot FAT_{CA,r,t}$$
$$+ QP_{WYP,r,t} \cdot FAT_{WYP,r,t} + QP_{OFP,r,t} \tag{114}$$

$PP..NFS_{MK,r,t}$: 0 = $(QP_{MK,r,t} - FU_{MK,r,t}) * NFS_{MK,r,t} + QP_{FDP,r,t} \cdot NFS_{FDP,r,t}$

$+QP_{BT,r,t} \cdot NFS_{BT,r,t} + QP_{CH,r,t} \cdot NFS_{CH,r,t} + QP_{SMP,r,t} \cdot NFS_{SMP,r,t}$

$+QP_{WMP,r,t} \cdot NFS_{WMP,r,t} + QP_{CA,r,t} \cdot NFS_{CA,r,t}$

$+QP_{WYP,r,t} \cdot NFS_{WYP,r,t} + QP_{ONP,r,t}$ (115)

Dairy producer prices at the EU-28 level are the market clearing prices. EU-15 prices are set equal to the EU-28 price, and EU-N13 prices are modelled as the EU-28 price multiplied by a quality factor .

2.6.3 Producer prices: sugar beet and sugar

One of the main components of the EU sugar policy is the minimum price or support price. The support price for sugar beet ($SP_{SBE,EUN,t}$), EUR 26.29 per tonne, is used as one of the elements in the calculation of the inside-quota sugar beet price to ensure a minimum price. The other element in the calculation is a weighted price of white sugar, molasses and by-products:

$$PP..QT_{SBE,EUN,t} =$$

$$max\left(SP_{SBE,EUN,t}, \begin{pmatrix} PP_{SWU,EUN,t} \cdot YLD..SBE_{SU,EUN,t} \\ +PP_{MOL,EUN,t} \cdot 0.5 + PP_{BP,EUN,t} \cdot 0.058 \end{pmatrix} \cdot MAR_{SBE,EUN,t}\right) \tag{116}$$

For the outofquota sugar beet price ($PP..NQT_{SBE,EUN,t}$), the calculation is done by weighting the white sugar price with the exports (in and out of quota), as well as the price of molasses, by-products and sugar beet for producing ethanol.

$$\begin{aligned} PP..NQT_{SBE,EUN,t} \\ &= \Big(\big(1 - BF..SHR_{SBE,EUN,t}\big) \\ &\cdot \big(f(\cdot) \cdot YLD..SBE_{SU,r,t} + PP_{MOL,EUN,t} \cdot 0.05 + PP_{BP,EUN,t} \cdot 0.058\big) \\ &\cdot MAR_{SBE,EUN,t} + BF..SHR_{SBE,EUN,t} \cdot PP..ET_{SBE,EUN,t}\Big) \,/\, g(\cdot) \end{aligned}$$

$$f(\cdot) = \big(NQT..EXSHR_{SU,EUN,t} \cdot EXP_{SUW,EUN,t} + \big(1 - NQT..EXSHR_{SU,EUN,t}\big) \cdot PP_{SUW,EUN,t}\big)$$

$$g(\cdot) = \big(1 + Log\big(ST..CF_{SU,EUN,t} + 1\big)/20\big) \tag{117}$$

Both, in and out-of-quota prices are used to calculate the sugar beet price ($PP_{SBE,r,t}$) by taking into account the in and outofquota production. When the sugar beet production ($QP_{SBE,r,t}$) does not exceed the quota ($QT_{SBE,r,t}$), that is $QP_{SBE,r,t} < QT_{SBE,r,t}$, the price is calculated as:

$$PP_{SBE,r,t} = max\ (PP..NQT_{SBE,r,t}, PP..QT_{SBE,EUN,t}) \tag{118}$$

Otherwise, the price is calculated as an average weighted price of the in and outofquota prices:

$$PP_{SBE,r,t} = \begin{pmatrix} max\big(PP..NQT_{SBE,EUN,t}, PP..QT_{SBE,EUN,t}\big) \cdot QT_{SBE,r,t} \\ +PP..NQT_{SBE,EUN,t} \cdot \big(QP_{SBE,r,t} - QT_{SBE,r,t}\big) \end{pmatrix} / QP_{SBE,r,t} \tag{119}$$

The sugar beet price for producing ethanol depends on the share of sugar beet in biofuel production. If this equals zero, ($BF..SHR_{SBE,EUN,t}=0$), then the price is calculated as a function of the sugar and by-product prices (i.e. molasses and dry beet pulp):

$$PP..ET_{SBE,EUN,t} = \left(\begin{array}{c} NQT..EXSHR_{SU,EUN,t} \cdot EXP_{SUW,EUN,t} \\ +\left(1 - NQT..EXSHR_{SU,EUN,t} \cdot PP_{SWU,EUN,t}\right) \cdot YLD..SBE_{SU,r,t} \\ +PP_{MOL,EUN,t} \cdot 0.05 \\ +PP_{BP,EUN,t} \cdot 0.058 \end{array} \right) \cdot MAR_{SBE,EUN,t} \qquad (120)$$

Otherwise, it is calculated as a function of ethanol and by-product prices.

$$PP..ET_{SBE,EUN,t} = \frac{\left(10 \cdot PP_{ET,EUN,t} \cdot BF..ET..CONV_{SBE,EUN,t} + PP_{BP,EUN,t} \cdot 0.058\right) \cdot MAR_{SBE,EUN,t}}{1 + Log\left(ST..CF_{SU,EUN,t} + 1\right)/20} \qquad (121)$$

Following the CAP reform, the support price for sugar is eliminated from year 2017, in parallel with the elimination of sugar quotas. This means that there is no price differential between the in- and out-ofquota, biofuel and market prices and, therefore, a unique price for sugar beet (i.e. market price):

$$PP..QT_{SBE,EUN,t} = PP..NQT_{SBE,EUN,t} = PP..ET_{SBE,EUN,t} = PP_{SBE,r,t} \qquad (122)$$

The sugar price for the EU-28 is solved in a market closing equation, ensuring a market balance for white sugar. As previously explained, the EU-15 price is set equal to the EU-28, and the EU-N13 is obtained using a quality factor. The elimination of quotas will allow prices in the EU to fall to the marginal cost of production and may allow a convergence towards world prices. The EU market will remain protected by the import tariff in the absence of this convergence.

2.6.4 World reference prices

World reference prices ($XP_{c,r,t}$) are used in Aglink-Cosimo to close the trade balances at world level. For arable crops, reference prices are set up at aggregated commodity level and not for individual crops. For pork and beef and veal, there are three segregated regional markets considered: foot and mouth disease endemic, Pacific and Atlantic. Reference world prices for each commodity are shown in Annex 3. Crude oil and fertiliser prices are also taken into account in the model. The general form of clearing equation for world markets in Aglink uses the net trade and the so-called 'statistical discrepancy'[11] ($SD_{c,r,t}$), which serves to close the balance and compensate differences in imports and exports:

$$XP_{c,r,t} : 0 = NT_{c,r,t} - SD_{c,r,t} \qquad (123)$$

World prices serve to calculate import (IMPc,r,t) and export prices (EXPc,r,t); this is a two-step process. First, a specific world price ($XP..R_{c,WLD,t}$) is set up for each region and, second, this price is made equal to the world price in order to facilitate the calibration procedure.

$$XP..R_{c,WLD,t} = XP_{c,WLD,t} \qquad (124)$$

The import ($IMP_{c,R,t}$) and export price ($EXP_{c,R,t}$) are identical and equal to the specific world price multiplied by the exchange rate for that region. These prices appear in the import and export equations:

$$IMP_{c,R,t} = EXP_{c,R,t} = XP..R_{c,WLD,t} \cdot XR_{c,R,t} \qquad (125)$$

11 This statistical discrepancy originates from lack of formal balancing of the underlying import and export trade statistics and projections worldwide. Typically, it stays below 3 % of the traded volume and is kept constant over the projection period as a convention.

2.6.5 Consumer prices

In order to make a difference between consumers and producers, consumer prices are explicitly modelled in Aglink-Cosimo. These prices are not used to balance domestic markets but calculated as functions of the producer prices and the GDP deflator in the following way:

$$Log\left(CP_{c,r,t}\right) = c + 1 - \xi_{CP_c,GDPD} \cdot GDPD_{r,t}$$
$$+\left(1 - \xi_{CP_c,GDPD}\right) \cdot Log\left(PP_{c,r,t}\right) + trend + R_{CP,r} \quad (126)$$

Consumer prices appear in the food demand functions ($F0_{c,r,t}$).

The value of the price–demand elasticities depend on how much of the raw product is needed for the production of the commodity used as reference for the consumer price, basically the amount of transformation from the raw product to the final consumer product (see Table 10). For example, butter, cheese, fresh dairy products, eggs and white sugar are products that require very little transformation to make them available to consumers.

Table 10: EU consumer to producer price elasticities used in Aglink-Cosimo

	EU-15	EU-N13
Cheese	0.3	0.3
Butter	0.7	0.7
Fresh dairy products	0.2	0.2
Skimmed milk powder	1	1
Whole milk powder	1	1
Casein	1	NA
Bovine meat	0.2	0.2
Pork	0.3	0.3
Poultry	0.4	0.4
Sheep meat	0.3	0.3
Eggs	0.4	0.4
Wheat	0.4	0.5
Coarse grains	0.5	0.6
Rice	0.5	0.6
Oilseeds	0.4	0.5
Cotton	0.28	NA
White sugar	0.3	0.3
Vegetable oils	0.6	0.7

2.7 Modelling of the Common Agricultural Policy

The intervention mechanism is up to 3 million tonnes per year for soft wheat, 50 000 tonnes for butter and 109 000 tonnes for skimmed milk powder. These quantities can be bought each year at fixed intervention prices. Beyond these limits, intervention is open by tender. The European Commission may also decide to open intervention by tender for durum wheat, barley, maize, paddy rice, and beef and veal.

Intervention purchases for barley, durum wheat, maize and rice intervention stocks (IST) are exogenous and set to zero. For soft wheat, intervention can be activated for scenarios through a specific price (EUN_WTS_SP). Public intervention stocks are endogenously modelled for white sugar, as well as for scenario analysis; therefore, they are set to zero in the baseline.

Butter and skimmed milk powder intervention stocks are set to zero because the probability of reaching intervention prices (on an annual basis) is very low considering current market prices. The same applies to beef.

Exceptional market measures, such as aided private storage, can be deployed to address severe market disturbances. These measures are not explicitly modelled, as they are taken on a case-by-case basis. Export refunds can now be granted only under these exceptional circumstances. There is no longer a trigger to grant export refunds, and subsidised exports are set at zero over the projection period. Nevertheless, as in the previous cases, they can be activated for scenario analysis.

Regarding production quotas, milk quotas were abolished in April 2015 and sugar and high-fructose corn syrup quotas will be abolished in October 2017.

Direct payments can be coupled or decoupled:

(i) *Coupled payments*. Further to the 2013 CAP reform, Member States can couple up to 8 % of their direct payments envelope (up to 13 %, in particular situations, or over 13 %, subject to the Commission's approval). Coupled payments are added to commodity prices as a top-up to the revenue that can influence production decisions. Coupled payments are traditionally significant for beef, sheep and cotton. Following the 2013 reform, coupled payments will also be granted in particular to milk, rice, sugar beet and durum wheat.

(ii) *Decoupled payments*. Following the 2013 CAP reform, further convergence of direct payments combined with the new distribution of entitlements will sometimes lead to major changes in farm subsidies and income. In addition, 'external convergence' will lead to a gradual increase in direct payments in the EU-N13 in parallel with a reduction in the EU-15.

It is assumed that decoupled payments have a small effect on production, currently set at 6 % ($SFP..CF_{agriculture,r,t}$). Only this share of the basic payment is added to the crop revenue.

Variables related to direct payments are defined according to the item they affect:

- EPA: direct payments affecting area (in EUR/ha);
- EPY: direct payments affecting yields (in EUR/t);
- EPI: direct payments affecting inventories (in EUR/head);
- EPQ: subsidy based on quantity produced (in EUR/t).

The amount of EPA is determined based on the decoupled payment envelopes for the EU-15 or EU-N13, divided by the total UAA. This means that not only the budget of the basic payment scheme, but also the greening payment, is accounted for (i.e. the underlying assumption is that all farmers respect the requirements and claim the payment). The use of total UAA leads to underestimating the payment per hectare, as the total number of entitlements (or the potentially eligible area) is smaller than the UAA. However, given the level of detail of the model (e.g. no distinction between regions) and the small impact on production, this approximation is considered to reflect reality.

The EPA payment is added to each crop revenue. For grass, the payment is instead redistributed to livestock as an equivalent payment per head accounted for in the inventory equation. The main principle behind this is to guarantee a minimum link with production that would be lower if the payment were linked to pasture. The EPA per hectare is multiplied by the number of grassland hectares. The distribution between ruminants is done using the same coefficients as used in the feed module.

For example, for beef the decoupled payment is calculated as follows:

$$SPF_{BV,E15,t} = SPF_{AG,E15,t} \cdot \frac{\left(AH_{PA,E15,t} + AH_{FO,E15,t}\right)}{\left(\frac{QP_{MK,E15,t}}{4.8} + \frac{QP_{BV,E15,t}}{0.6} + QP_{SH,E15,t}\right)/0.6} \tag{127}$$

The decoupled and coupled payments for beef are summed up in an EPQ variable calculated per tonne and used in the suckler cow inventory equation, where EPI..BUDGET is the envelope of voluntary coupled support.

$$EPQ_{BV,E15,t} = \frac{EPI..BUDGET_{BV,E15,t}}{QP_{BV,E15,t}} + \left(SPF_{BV,E15,t} \cdot SPF..CF_{BV,E15,t}\right) \tag{128}$$

For sheep and goats, the modelling is similar to beef except that the coupled payment level is determined exogenously.

For milk, the coupled and decoupled payments are aggregated in the EPI variable ($EPI..DP_{MK,E15,t}$), which is calculated per tonne of milk. This variable is determined exogenously, in a similar way to the voluntary coupled support envelope ($EPI..BUDGET_{BV,E15,t}$):

$$SPF_{BV,E15,t} = EPI..DP_{MK,E15,t} + (SFP_{MK,E15,t} \cdot SFP..CF_{RU,E15,t}) \tag{129}$$

Regarding greening measures, the area of permanent grassland as a proportion of total agricultural area is exogenously kept constant over the outlook period. As regards the Ecological Focus Area (EFA), it should be emphasised that fallow land is only one of the area types qualifying for the measure. In many Member States, farmers can use areas under nitrogen-fixing crops, catch crops such as mustard or green cover, and landscape features, for example, to meet the EFA requirement of 5 % arable land. That is why, for the time being, the coefficient reflecting the policy-driven set-aside ($AD..SHR_{set,\,r,t}$) is kept at 1.

The EU module reflects the CAP reform only in part, because the assessment of the production impacts of all the measures is not yet complete. Furthermore, given the geographical aggregation of the model, it is not possible to capture the redistribution of direct payments within Member States and regions. Similarly, the voluntary capping of payments over EUR 150 000 and specific schemes for small farmers and young farmers are not accounted for. The effect of the redistributive payment, a top-up to the basic payment for the first hectares of the holding, as implemented by eight Member States, is also not taken into account.

2.8 EU income module

The EU income module is a satellite module, which means that the module is not a part of the original Aglink-Cosimo model. It aims to project agricultural income at the EU level. When possible, the projections of the income components are an extrapolation of the modelling exercise. When this is not possible, other methods are used (e.g. for workforce and subsidies). The way in which each item is projected is detailed in Table 11.

Table 11: Income module components

Item	Projected according to:
Value of production (VP)	
– Aglink products	Changes in producer prices and production quantities
– non-Aglink products	Change in VP-Aglink and GDPI
– other products	Linear trend (forecast formula Excel; based on 2000 – last year available)
Subsidies	Direct payment ceilings following the CAP reform (share of coupled and decoupled payments is assumed to be similar to the current situation)
Intermediate costs	
– seed	Change in acreage harvested and coarse grain price
– feed	Change in feed use and prices in marketing year *N* and year *N* – 1.
– energy and fertiliser	The change in the quantity produced of Aglink products and the change in energy price, in which the energy price is a function of the world oil price
– other	Change in CPI
Taxes	Linear trend
Fixed capital consumption	The change in the quantity produced of Aglink products and in CPI
Workforce	Exponential growth trend

Note: *Aglink products are the commodities covered in Aglink-Cosimo. Non-Aglink products include, for example, wine and olive oil. In 2012, non-Aglink products represented 35 % of the value of production in the EU*
CPI, consumer price index; GDPI, gross domestic production index

The statistical basis of the projections for agricultural income is the Economic Accounts for Agriculture (EAA). For subsidies, the data includes all coupled and decoupled payments, including state aid and production-related rural development support but does not include investment subsidies.

The value of production of Aglink products for historic data is directly taken from the EAA, whereas projected values are made up of the change in prices (PP) and production volumes (QP) of the modelled commodities. Because in these two cases different data sources are used, the changes in values instead of absolute values are used:

$$VP_{c,r,t} = VP_{c,r,t-1} \cdot \left(\frac{QP_{c,r,t}}{QP_{c,r,t-1}}\right) \cdot \left(\frac{PP_{c,r,t}}{PP_{c,r,t-1}}\right) \tag{130}$$

The VP for non-Aglink commodities is based on the growth in the value of production of Aglink commodities and the change in GDP. For the EU-15, both are weighted equally:

$$\mathrm{VP}_{\mathrm{non-Aglink,E15,t}} = \mathrm{VP}_{\mathrm{non-Aglink,E15,t-1}} \cdot \left(\frac{\left(\frac{VP_{Aglink,E15,t}}{VP_{Aglink,E15,t-1}}-1\right)}{2} + 1\right) \cdot \left(\frac{\left(\left(\frac{GDPI_{E15,t}}{GDPI_{E15,t-1}}\right)+1\right)}{2}\right) \tag{131}$$

As the growth in GDP in the EU-N13 is relatively high, higher than the expected growth in non-Aglink products, the growth in GDP has a smaller influence (one-third), such that:

$$VP_{non-Aglink,NMS,t} = VP_{non-Aglink,NMS,t-1} \cdot \left(\frac{\left(\frac{VP_{Aglink,NMS,t}}{VP_{Aglink,NMS,t-1}} - 1 \right)}{2} + 1 \right) \cdot \left(\frac{\left(\frac{GDPI_{NMS,t}}{GDPI_{NMS,t-1}} + 2 \right)}{3} \right) \tag{132}$$

The value of production for 'other' products captures mainly the value of production of the agricultural services and is assumed to follow the same linear trend as observed in the year 2000, which is obtained by using a forecast formula.

Total intermediate cost is the sum of the expenditure on seed, feed, energy and fertiliser and other. The projected expenditure on seed is based on the change in area harvested and the change in the producer price. The feed expenditure in year t is calculated as an average of feed use and prices in marketing years t and $t-1$:

$$FEEXP_t = 0.5\ (PP_{APF,t} \cdot FE_{APF,t} + PP_{APF,t-1} \cdot FE_{APF,t-1}) \tag{133}$$

where $FEEXP_t$ is the feed expenditure in year t, $PP_{APF,t}$ the weighted average of the different feed prices in year t and $FE_{APF,t}$ the total of the different feed uses in year t. The feed components considered for the calculation are low-protein feed commodities (i.e. wheat, coarse grains, milling by-products, molasses, beet pulp and manioc), medium-protein feed commodities (i.e. dried distiller's grains, corn gluten feed, field peas and whey powder) and high-protein feed commodities (i.e. protein meal, fish meal, meat and bone meal and skimmed milk powder).

The expenditure on energy and fertiliser is based on the change in the quantity produced and the change in the price of on-farm energy. The price of on-farm energy ($ENPI_{EUN}$) is a function of the world oil price ($PP_{oil,wld}$), obtained by a linear regression in which liquid fuel prices are taken as a proxy for on-farm energy, such that:

$$ENPI_{EUN} = 35.95 + 1.4556 \cdot PP_{OIL,WLD} \cdot USD / EUR \tag{134}$$

The size of the agricultural workforce is assumed to follow the same exponential trend as has been observed since 2005. The reason why 2005 was chosen was to avoid the effect of the 2004 enlargement. Corrections in the historical data were also made, as the EAA data on workforce (i.e. based on the Fertility and Family Survey) sometimes demonstrated big inconsistencies in the time series. An exponential growth trend was calculated for this purpose. The first year of this projection showed a sharp decrease compared with the following years. Statistically correct since the last data point (2012), it was relatively high compared with the projected trend, but in practice this is not what we would expect. Therefore, the same percentage change in the projected trend is applied to the first year of the projection.

We attempted to make baseline estimates in line with latest figures on agricultural income from Eurostat.

3. Model calibration

3.1 Basic approach

In general, the process of calibration can be defined as finding the values for a subset of model variables to reproduce a historical or projected state of the economy, often called a benchmark, reference or baseline scenario. The EU Outlook incorporates a formal calibration exercise for the EU model component of Aglink-Cosimo, following the approach taken by the OECD and FAO Secretariats in the yearly elaboration of the OECD/FAO Agricultural Outlook. The underlying model in this exercise, Aglink-Cosimo, is constructed in such a way that it provides a flexible framework to integrate different sources of information, such as historical market trends and market expert information, in an economically consistent model. This is possible through the so-called 'calibration factors', which can be used as variables in the exercise.

The variables targeted are those that characterise commodity market balances on the supply side (i.e. area/area shares, yields and production), demand side (i.e. feed, food, fuel and industrial consumption), trade side (i.e. imports and exports) or stocks. These variables are typically endogenous in multi-commodity market models and are treated differently during calibration. Indirect assumptions that are only implicitly defined by functional forms or model parameters are more difficult to harmonise. These assumptions include, for instance, changes in consumption patterns, production technologies or feed conversion ratios over time.

3.2 Database and assumptions

3.2.1 Data sources

Prices

Most of the prices are based on the Member States notifications to DG AGRI. The EU-28 price corresponds to the EU-15 average price to ensure longer time series without breaks (except for milk)[12]. Prior to EU accession in 2004, the average price for the new Member States is estimated as the EU-15 price multiplied by the observed ratio between the two prices in 2004.

Oilseeds, meals and oils prices are taken from OIL WORD[13]. For biodiesel and ethanol the prices in F.O. Licht's World Ethanol & Biofuels Report are used.

For crops, annual averages are calculated for the marketing year:

- cereals (except rice): July year *t*/June year *t* + 1;
- oilseeds: October year *t*/September year *t* + 1;
- sugar: September year *t*/August year *t* + 1;
- rice: September year *t*/August year *t* + 1.

For the other commodities, a calendar year (January year *N*/December year *N*) is used (see tables 12 and 13).

12 Most of the prices can be found at http://ec.europa.eu/agriculture/markets-and-prices/price-monitoring/index_en.htm

13 www.oilworld.biz

Table 12: Price references used in the EU module and for the world market of crops and biofuels

Commodity	OECD/FAO – World price references	EU module – EU price references
Soft wheat	No 2 Hard red winter wheat, US Gulf (June/May)	Common wheat, breakmaking quality
Durum wheat	NA	Durum wheat
Barley	NA	Feed barley
Maize	No 2 Yellow corn, US Gulf (Sept/Aug)	Feed maize
Oats	NA	Feed oats
Rye	NA	Breadmaking rye
Other cereals	NA	Feed rye
Rice	Milled 5 % broken, f.o.b. Ho Chi Minh (Jan/Dec)	Rice paddy, Japonica, in Italy (Lido)
Sugar	Refined sugar price, Euronext, Europe (Oct/Sept)	White sugar
Rapeseed	Weighted average oilseed price, European port	Europe, 00, c.i.f. Hamburg
Soybeans		Brazil, c.i.f. Rotterdam (1993–1995; Argentine, c.i.f. Rotterdam)
Sunflower		EU, c.i.f. Amsterdam
Rapemeal	Weighted average meal price, European port	34 %, f.o.b. ex-mill Hamburg
Soymeal		48 %, Brazil, c.i.f. Rotterdam
Sunmeal		37/38 %, Argentine, c.i.f. Rotterdam until 2011. Starting from 2012, Ukraine, DAF
Rape oil	Weighted average price of oilseeds oils and palm oil, European port	Dutch, f.o.b. ex-mill
Soybean oil		Dutch, f.o.b. ex-mill
Sun oil		EU, f.o.b. north-west Europe ports
Palm oil		Crude, 5 % FFA, Malaysia/Indonesia, c.i.f. north-west Europe
Biodiesel	Producer price Germany net of biodiesel tariff	Germany (UFOP), B-100
Ethanol	Brazil, São Paulo (ex-distillery)	EU, new, f.o.b.. T2

Note: f.o.b. refers to 'free on board' and c.i.f. to 'cost , insurance and freight'

Table 13: Price references used in the EU module and the world market of animal products		
Commodity	**World reference prices (OECD/FAO, see Annex 3)**	**EU reference prices (EU module)**
Beef	USA: choice steers Brazil: average beef producer price	Young bulls R3
Pig meat	USA: barrows and gilts Brazil: average pig producer price	Class E
Sheep meat	New Zealand: lamb price, all grades available	Heavy lamb
Poultry meat	Brazil: average chicken for slaughter	Chicken (all)
Milk	NA	Farm gate price, real fat content. The EU-28 price is an average of the EU-15 and EU-N13 prices weighted by production in Aglink-Cosimo
Cheese	Oceania: cheddar cheese	Cheddar
Skimmed milk powder	Oceania: non-fat dry milk	SMP intervention quality
Whole milk powder	Oceania: WMP	WMP
Butter	Oceania: butter	Butter

Note: For beef and pig meat, the world market is split mainly into two markets, Atlantic and Pacific.

Consumer prices

Historical data comes from the International Labour Organization (ILO) database LABORSTA[14]. The data are available only by Member State up to 2008. From 2009 onwards, the consumer price equation in the model is used to estimate consumer prices.

14 Group of topics: consumer prices/retail prices of 93 food items (ILO October Inquiry). Table: retail prices of selected food items (O2). Available at http://laborsta.ilo.org/STP/guest

The choice of the commodity/country price used as reference is mainly driven by the completeness of the time series available and the representativeness of the Member State domestic market within the EU (see table 14).

Table 14: References for consumer prices in the EU

Commodity	EU region	Country of reference	Retailed product
Wheat	EU-15	Italy: Rome	Wheat flour, white
	EU-N13	Poland	
Coarse grains	EU-15	Denmark: rye bread	Rye bread
	EU-N13	Poland: rye bread	
Rice	EU-15	Italy: Rome	Rice, long grain
	EU-N13	Poland	
White sugar	EU-15	Italy: Rome	Sugar, white
	EU-N13	Hungary	
Oilseeds	EU-15	Luxembourg	Peanuts (groundnuts), without shells
	EU-N13	Hungary	
Vegetable oil	EU-15	France	Salad or cooking oil
	EU-N13	Poland	
Beef	EU-15	Netherlands	Beef, with bone
	EU-N13	Poland	
Pig meat	EU-15	France	Pork, with bone
	EU-N13	Latvia	
Sheep meat	EU-15	Italy: Rome	Lamb, leg
	EU-N13	Bulgaria	
Poultry	EU-15	Austria	Chicken, cleaned
	EU-N13	Czech Republic	
Eggs	EU-15	Sweden	Chicken eggs, fresh
	EU-N13	Poland	
Butter	EU-15	France	Butter
	EU-N13	Poland	
Cheese	EU-15	Denmark	Cheese, other
	EU-N13	Poland	
Fresh dairy products	EU-15	France	Cow's milk, fresh, whole, pasteurised
	EU-N13	Hungary	
Skimmed milk powder	EU-15	Portugal	Cow's milk, powdered, skimmed (non-fat)
	EU-N13	Missing	
Whole milk powder	EU-15	Portugal	Cow's milk, powdered, whole
	EU-N13	Hungary	
Ethanol	EU-28	France	France E-85

Balance items[15]

EU commodity market balances are calculated by DG AGRI. For crops, the supply of meat, milk and dairy products, area and livestock figures are based on Eurostat data. The balance is first established for the EU-28, starting with production and trade (based on Comext). Stocks (including private stocks) are estimated and consumption is calculated residually to close the market balance. For the EU-15 and EU-N13, given that intra-trade figures are not always reliable, consumption in one of the two regions is calculated as the difference between consumption in the EU-28 and in the other region. In this case, intra-trade exports or imports are adjusted to match these consumption figures. For dairy products, EU aggregates are often missing from Eurostat owing to confidentiality issues at Member State level and, therefore, are estimated by DG AGRI.

For the biofuel module, production figures are compiled by combining different sources: mainly Eurostat, Enerdata, and F.O. Licht. For ethanol feedstocks, Member States have an obligation to declare to the European Commission their production of ethyl alcohol by feedstock (cereals, beet, wine).[16] The main source for biodiesel production based on vegetable oils is F.O. Licht. Regarding the use of waste oils, information received from DG Energy is used. Fossil fuel consumption comes from the POLES model.

Feed module

Regarding the data used for the feed module, trade data are obtained at the HS-6 level from FAOSTAT, UN Comtrade and national statistical agencies (such as the United States Department of Agriculture (USDA) Foreign Agricultural Service trade database and Statistics Canada). Production data are also obtained from FAOSTAT. In the case of cereal bran, data are available in the FAOSTAT food balance sheets. Production data for other feeds such as dried beet pulp, corn gluten feed, dried distiller's grains and meat and bone meals (MBM) are linked to their main product and calculated using fixed conversion factors. Production of meat and bone meals was calculated directly from beef, veal, pork, sheep meat and poultry slaughter production, using conversion factors obtained from livestock experts. These conversion factors have been adjusted to minimise the errors in the years of available data and kept for the other years. For the new feeds, in general total consumption (except for corn gluten and cereal bran in the USA) has been calculated residually, assuming no stocks. Therefore, the amount consumed as feed is assumed to be equal to the total consumption, except for molasses in all Aglink countries and cereal bran in China.

National prices of these new feed products can easily be calculated from international recognised prices, as tariffs are small or equal to zero for most Aglink commodities. There are obviously a few exceptions, such as the price paid for skimmed milk powder for feed in the EU, which was not the same as the market price before 2008 (and especially before 2006) owing to a large consumer subsidy.

Most world price indicators for these new feeds are the prices in the USA, considering the large amount of products in that market, the availability of data in the USDA feed database and the degree of market openness. However, manioc is the exception here. The international recognised price for manioc has for a long time been the price reported in Rotterdam. With the structural change created by the realignment of EU and world cereal prices, barely any manioc is now traded in Rotterdam, or at least not enough to establish a reliable price. Instead the unit export price of dry cassava from Thailand was used.

3.2.2 Macroeconomic assumptions

The assumptions for the crude oil price (Brent), the population, the GDP growth (in real terms), the GDP deflator, the consumer price index (CPI) and the exchange rate for the main players in agricultural markets are derived from IHS Global Insight. For the EU, the database of the Directorate General for Economic and Financial Affairs (Ameco) is used.

15 More details on the methodology can be found at: http://ec.europa.eu/agriculture/markets-and-prices/short-term-outlook/index_en.htm.

16 This information is available at http://ec.europa.eu/agriculture/markets/wine/facts/index_en.htm

3.3 Outlook process and outreach events

As described above in the introduction to this section, the validation process is the step that allows the transfer from model results to the European Commission annual medium-term (10-year) baseline projections for agricultural commodity markets. These projections are published annually by the European Commission's DG AGRI in the second half of the year: http://ec.europa.eu/agriculture/markets-and-prices/medium-term-outlook/index_en.htm

3.3.1Meltdown week

After the recalibration of the EU component of the previous OECD/FAO baseline (usually released in June), on the basis of an updated and consistent set of medium-term macroeconomic projections and additional information from the short-term EU Outlook, a preliminary baseline is obtained. This baseline can deviate from the short-term figures, for reasons already explained above: as the whole system of equations is solved simultaneously and only the EU component is recalibrated, changes in net trade with the EU may lead to changes in domestic and world prices. Having said that, the market balancing equations in Aglink-Cosimo will also ensure that any inconsistencies are removed.

This preliminary baseline is examined and consolidated during a 'meltdown' week, organised on a yearly basis in Brussels (around September to October). Experts from DG AGRI (economic analysis and market units) and JRC-IPTS, and, if appropriate, other organisations involved in projections, gather to comment on commodity markets by group (i.e. arable crops, sugar and biofuels, meat, milk and dairy products), as well as on the results of the income module. This is an opportunity to benefit from up-to-date expertise on each market (recent developments and expert judgement on trends and outlook) and achieve consensus on the projections. This implies a certain degree of calibration of model parameters.

Meltdown week is also the opportunity to run the model for the stochastic draws described hereafter in this section and in section 4. This exercise allows the detection of plausible situations in terms of yield and/or macroeconomic conditions that cannot be reproduced by the models. When the rate of success falls significantly, this indicates that certain parameters need to be reassessed.

3.3.2 Outlook workshop

The preliminary baseline is presented to policy makers, modellers, researchers, market experts and stakeholders of EU and international relevance during an annual workshop, organised jointly by DG AGRI and JRC-IPTS since 2007. The workshop offers an opportunity to verify the reliability of the results obtained and to discuss how different settings and assumptions regarding macroeconomic factors and other uncertainties may influence the projections of individual commodity markets.

The workshop is usually organised around session(s) dealing with the macroeconomic and/or policy assumptions and sessions addressing groups of commodities. In the latter, baseline projections are presented, as well as specific deterministic and uncertainty scenarios, by the European Commission. Experts are invited to comment on the baseline proposed and to present some specific issues of relevance for the markets concerned. These presentations are followed by a general discussion. The proceedings of each of these workshops have been published[17].

Suggestions and comments made during the workshop are taken into account in order to improve the baseline projections and further calibrate the model. A final baseline is then elaborated and published as the EU Outlook (*Prospects for Agricultural Markets and Income in the EU*).

3.3.3 Scenarios and stochastic analysis

Around the baseline assumptions concerning policy context, macroeconomic conditions and yield estimates, Aglink-Cosimo is also used to assess what would happen under different assumptions. This can be done either by scenario analysis or by analysing the model results of a subset of stochastic draws ('subset analysis').

17 2013 edition: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=6822
2014 edition: http://agrilife.jrc.ec.europa.eu/documents/JRC92558.pdf
2012 edition: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=5500
2011 edition: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=4859
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2009 edition: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3700
2008 edition: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2239
2007 edition: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1699

Scenario analysis implies assessing the model results when some specific assumptions and/or parameters are changed and comparing them with the baseline. In this case, the model is simulated once for each scenario, with some adjustments in parameters and/or equations reflecting the scenario. A recent example has been carried out in the EU Outlook 2012 concerning the EU biofuel policy. In this case, the baseline assumption was that, by 2020, the EU will not have reached the 10 % renewable energy in transport target (hereafter called the 'mandate'), as a result of delays in the initial phases of expansion in the use and production of biofuels. Two alternative scenarios were tested: (i) the 10 % mandate is fulfilled; and (ii) EU policy is amended in order to reduce the production of biofuels from food crops (first-generation biofuels) to 5 %. This scenario showed at that time that, in the case of a target fully met, this would be done mainly through extra imports of biofuels and, in the case of a reduced share of biofuels from food crops, the impact on the EU domestic price would be modest for most feedstock crops, but more important for vegetable oils.

Subset analysis consists of selecting within the number of stochastic draws those corresponding to some macroeconomic and/or yield conditions. In this case, in contrast to scenario analysis, the model is run for each of the draws composing the subset, but no parameter and/or equation is changed in the model. Several examples can be found in the EU Outlook 2013 concerning a lower oil price, lower maize yield in the USA, lower growth and exchange rate in Brazil and a lower euro exchange rate. More details are shown in section 4 concerning uncertainty assessments through partial stochastic analysis.

3.3.4 World Outlook Conference

Every year, in spring, the community of institutions aiming to publish medium-term projections, principally elaborated through the use of the Aglink-Cosimo model, either as a whole or by individual modules, gathers in an informal 'World Outlook Conference' (WOC), at which participants exchange views on their projections and on all issues of interest that they encounter during the elaboration of their projections. This community includes the European Commission (DG AGRI and JRC-IPTS), OECD, FAO, IFPRI (International Food Policy Research Institute), USDA (Office of the Chief Economist and Economic Research Service), FAPRI (Food and Agricultural Policy Research Institute), Agriculture and Agri-Food Canada, JIRCAS (Japanese International Research Center for Agricultural Sciences), etc. The OECD and FAO usually present preliminary baseline results for discussions under embargo.

4 Applications

4.1 Uncertainty analysis

The European Commission's annual projection is based on normal conditions surrounded by different sources of exogenous uncertainties, such as yield and macroeconomic fluctuations. The main objective of the uncertainty analysis is to assess and quantify how uncertainty surrounding the assumptions about the general macroeconomic setting (including the crude oil price) and crop yield levels might affect the projected agricultural market developments, and in particular the extent to which this exogenous uncertainty is transmitted to various elements of the baseline projections.

4.2 Partial stochastic analysis

Partial stochastic analysis serves to identify which variables in the projection are more affected by the exogenous uncertainty. Some of its applications are:

- observing the response to a certain policy that is triggered because of some threshold, e.g. support price;
- analysing the impact on the projection of extreme uncertainty values, for example the robustness of baseline projection and its variation for medium-term projections in the case of high or low crude oil prices and/or drought in major producing areas;
- inconsistencies in the model outcomes that suggest the need to re-specify one or more of the model equations;
- limitations to this approach include its 'partial' nature, as it takes into account only the uncertainty in a limited number of *specific external* factors, as chosen by the analyst; in addition, it relies on future variability in exogenous factors that are based on their variability in the past, whereas uncertainty in these variables might, for example, increase or become more correlated in the future.

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6. Annexes

6.1 ANNEX 1: List of regions

Countries in Aglink			Countries in Cosimo			
OECD countries			**OECD countries**		**Cosimo aggregates**	
Australia	AUS		Chile	CHL	LDC Oceania	OCL
Canada	CAN		Israel	ISR	Other Oceania	OCE
Switzerland	CHE		Turkey	TUR	Other South America and Caribbean	SAC
Japan	JPN				LDC sub-Saharan Africa	AFL
South Korea	KOR		Non-OECD countries		Other sub-Saharan Africa	AFS
Mexico	MEX		Bangladesh	BGD	Other North Africa	AFN
Norway	NOR		Colombia	COL	LDC Asia	ASL
New Zealand	NZL		Algeria	DZA	Other Asia Developing	ASA
United States of America	USA		Egypt	EGY	Other Asia Developed	ASD
			Ethiopia	ETH	Other Middle East	MLE
OECD country aggregates			Ghana	GHA	Other Eastern Europe	EUE
European Union 28	EUN		Indonesia	IDN	Other Western Europe	EUW
			India	IND		
			Iran (Islamic Republic of)	IRN		
Non-OECD countries			Kazakhstan	KAZ		
Argentina	ARG		Mozambique	MOZ		
Brazil	BRA		Malaysia	MYS		
China	CHN		Nigeria	NGA		
Russia	RUS		Pakistan	PAK		
			Peru	PER		
			Philippines	PHL		
			Paraguay	PRY		
			Saudi Arabia	SAU		
			Sudan	SDN		
			Thailand	THA		
			United Republic of Tanzania	TZA		
			Ukraine	UKR		
			Uruguay	URY		
			Vietnam	VNM		
			South Africa	ZAF		
			Zambia	ZMB		
			Haiti	HTI		

LDC, least developed country

6.2 ANNEX 2: List of commodities in Aglink-Cosimo

CEREALS			**SUGARS AND SWEETENERS**			**DAIRY PRODUCTS**	
Wheat	**WT**		**Sugar beet**	**SBE**		**Milk**	**MK**
Durum wheat	WTD		**Sugar cane**	**SCA**		Fat content	FAT
Soft wheat	WTS		**Sugar and molasses**	**SUMOL**		Non-fat solids	NFS
Coarse grains	**CG**		**Sugar**	**SU**		**Butter**	**BT**
Barley	BA		**Raw sugar**	**SUR**		**Cheese**	CH
Maize	MA		**White sugar**	**SUW**		**Whole milk powder**	WMP
Oats	OT		**Molasses from sugar**	**MOL**		**Skimmed milk powder**	SMP
Sorghum	SO		**High-fructose corn syrup**	**HFCS**		**Fresh dairy products**	FDP
Rye	RY		**Sweetener**	**SW**		**Other dairy products (ice cream, yoghurt, evaporated milk, cottage cheese)**	ODP
Other cereals	OC		Coarse fructose	CF		Whey powder	WYP
Rice	RI		Gur (jaggery or brown sugar)	GUR		Casein	CA
Millet	MT					Sheep's milk	MKS
						Goat's milk	MKG
VEGETABLE OIL PRODUCTS			**OTHER CROPS**			**ANIMAL PRODUCTS**	
Oilseeds	**OS**		Beans	BN		**Beef and veal**	**BV**
Soybean	SB		Cotton	CT		**Pigmeat**	**PK**
Rapeseed	RP		Cottonseed	CSE		**Poultry meat**	**PT**
Sunflower seed	SF		Cottonseed meal	CSM		Chicken	CK
Other oilseeds	OOS		Cottonseed oil	CSL		Chicken white	CKW
Protein meals	**PM**		**Roots tubers**	**RT**		Chicken brown	CKB
Palm kernel meal	KM		Jatropha	JA		**Sheep meat**	**SH**
Copra (coconut meal	CM		Field peas	FP		Mutton	MU
Groundnut meal	GM					Lamb	LA
Oilseed meals	OM		**ENERGY RELATED PRODUCTS**			Wool	WL
Soybean meal	SM		Biofuels	BF		**Eggs**	EG
Rapeseed meal	RM		**Ethanol**	**ET**		Fish	FH
Sunflower meal	SFM		**Biodiesel**	**BD**		Other poultry	OP
Vegetable oils	**VL**		Crude oil	OIL		**FEED PRODUCTS**	
Palm oil	PL		Diesel	DIE		**Feed**	FE
Palm kernel oil	KL		Gasoline	GAS		Corn gluten feed	**CGF**
Copra (coconut) oil	CL		Fertiliser	FT		Dried distiller's grains	**DDG**
Groundnut oil	GL					Protein feed	**PF**
Oilseed oils	OL					Cereal brans	**CEB**
Soybean oil	SL					Dried beet pulp	**BP**
Rapeseed oil	RL					Manioc	**MN**
Sunflower oil	SFL					Meat and bone meal	**MBM**
						Fish meal	**FM**
						Fish oil	**FL**

Note: All endogenous products in the model are shown in bold

6.3 ANNEX 3: World market clearing prices in Aglink-Cosimo

Cereals	
Wheat	No 2 Hard red winter wheat, ordinary protein, United States f.o.b. Gulf ports (June/May)
Coarse grains	No 2 Yellow corn, United States f.o.b. Gulf Ports (September/August)
Rice	Milled, 5% broken, f.o.b. Ho Chi Minh (January/December)
Oilseeds	
Oilseeds	Weighted average oilseed price, European port
Protein meals	Weighted average meal price, European port
Vegetable oils	Weighted average price of oilseed oils and palm oil, European port
Fibre crops	
Cotton	Cotlook A index, Middling 1 3/32", c.f.r. far Eastern ports (August/July)
Sweeteners	
Raw sugar	Raw sugar world price, ICE contract No 11 nearby, October/September
White sugar	Refined sugar price, Euronext, Liffe, Contract No 407 London, Europe, October/September
High-fructose corn syrup	United States wholesale list price HFCS-55, October/September
Molasses	Unit import price, Europe (October/September)
Meats	
Beef and veal, price EU	EU average beef producer price
Beef and veal, price US	US choice steers, 1 100–1 300 lb lw, Nebraska – lw to dw conversion factor 0.63
Beef and veal, price BRA	Brazil average beef producer price
Pigmeat, price EU	EU average pigmeat producer price
Pigmeat, price US	US barrows and gilts, No 1–3, 230–250 lb lw, Iowa/South Minnesota – lw to dw conversion factor 0.74
Pigmeat, price BRA	Brazil average pigmeat producer price
Poultry, price EU	EU average producer price
Poultry, price US	US wholesale weighted average broiler price, 12 cities
Poultry, price BRA	Brazil average chicken for slaughter producer price
Sheep meat	New Zealand lamb schedule price, all grade average
Fish and seafood	
Fish	World unit value of trade (sum of exports and imports)
Fish from aquaculture	World unit value of aquaculture fisheries production (live weight basis)
Fish from capture	FAO estimated value of world ex vessel value of capture fisheries production excluding that for reduction
Fish meal	Fish meal, 64 65 % protein, Hamburg, Germany

Fish oil	Fish oil any origin, north-west Europe
Dairy products	
Butter	F.o.b. export price, butter, 82 % butterfat, Oceania
Cheese	F.o.b. export price, cheddar cheese, 39 % moisture, Oceania
Skimmed milk powder	F.o.b. export price, non-fat dry milk, 1.25 % butterfat, Oceania
Whole milk powder	F.o.b. export price, WMP 26 % butterfat, Oceania
Whey powder	Dry whey, west region, United States
Casein	Export price, New Zealand
Biofuels	
Ethanol	Brazil, São Paulo (ex-distillery)
Biodiesel	Producer price Germany net of biodiesel tariff
Feed products	
Dried distiller's grains	Wholesale price, central Illinois, USA
Dried beet pulp	Dried beet pulp unit export price of the USA
Cereal brans	Wheat bran price Kansas City, USA
Meat and bone meal	Meat and bone meal price, central USA
Corn gluten feed	Corn gluten feed price, 21 % protein, Midwest, USA
Roots, tubers	Dry cassava, Thai export price

6.4 ANNEX 4: Regions, commodities and items in the EU Aglink module

Region			**Commodity**			**Item**	
EUN	European Union 28		CG	Coarse grains		AH	Area harvested; kha
E15	European Union 15 (original 15 Member States)		WT	Wheat		AH..SHR	Share of product area in agricultural product area; %
NMS	European Union 13 (new Member States)		OS	Oilseeds		BF	Biofuel feedstock
US	United States		RI	Rice		BF..SHR	Share of biofuel use in total consumption; %
PAC	Pacific meat market		PA	Pasture		CI	Cow inventory; head
ATL	Atlantic meat market		OX	Land devoted to crops other than cereals, oilseeds, pasture and fodder crops		CI..NQT	Non-quota cow inventories; head
WLD	World		OL	Oilseed oils		CP	Consumer price; national currency/t
			VL	Vegetable oils		CPCI	Cost of production index; index
			OM	Oil meals		CR	Crushed; kt
			PM	Total protein meal		CRMAR	Crush margin; national currency/t
			SB	Soybean		CW	Average carcass weight; t/head
			RP	Rapeseed		DEL	Deliveries to dairies; kt
			SF	Sunflower seed		EPA	Effective support payments; national currency/ha
			BA	Barley		EPA..DP	Payment equivalent affecting area; EUR/ha or EUR/t
			MA	Maize		EPI	Effective support payments; national currency/head
			DDG	Dried distiller's grains		EPI..BUDGET	Equivalent payment of all payments to beef and veal producers, as stated in the EU budget; EUR
			WTS	Soft wheat		EPQ	Effective support payments; local currency/t
			CL	Copra (coconut) oil		EX	Exports; kt
			CM	Copra (coconut) meal		EX..SUB	Subsidised exports; kt
			KL	Palm kernel oil		EX..SUBSHR	Export share of subsidised sugar in out-of-quota sugar; decimal
			KM	Palm kernel meal		EX..UNS	Unsubsidised exports; kt
			CGF	Corn gluten feed		EXM	Meat exports; kt

Region			Commodity			Item	
			HFCS	High-fructose corn syrup		EXM..ATL	Meat exports to the Atlantic market (pork, EUN); kt
			MOL	Molasses from sugar		EXM..PAC	Meat exports to the Pacific market (pork, EUN); kt
			SBE	Sugar beet		EXM..SUB	Meat subsidised exports; kt
			SUR	Raw sugar		EXM.. UNS	Meat unsubsidised exports; kt
			SU	Sugar		EXM.. XCHN	Meat exports to China; kt
			SW	Sweetener		EXP	Exports price; local currency/t
			SUW	White sugar		FAT	Fat; %
			BD	Biodiesel		FC..CG	Fix costs of biofuels production from coarse grains; LC per million litres
			ET	Ethanol		FC..SBE	Fix costs of biofuels production from sugar beet; LC per million litres
			GAS	Gasoline		FC..VL	Fix costs of biofuels production from vegetable oils; LC per million litres
			DIE	Diesel		FC..WT	Fix costs of biofuels production from wheat; LC per million litres
			PK	Pork		FCR	Feed conversion ratio
			SH	Sheep		FE	Feed consumption; kt
			MK	Milk		FE..SHR	Feed share in coarse grains feed; decimal
			FDP	Fresh dairy products		FECI	Feed expenditure index; %
			BT	Butter		FO	Food consumption; kt
			CH	Cheese		FO..SHR	Food share; decimal
			SMP	Skimmed milk powder		FU	Farm use; kt
			WMP	Whole milk powder		HFCS	Used for HFCS; kt
			WYP	Whey powder		IM	Imports; kt
			ME	Macro variables		IM..EBA	Imports, EBA; kt
			CA	Casein		IM..OTH	Imports, excluding intra-trade, other; kt rse
			GN	Groundnut		IM..SHR	Import share, decimal
			CSE	Cottonseed		IMM	Meat imports; kt
			SL	Soybean oil		IMP	Import price; LC/t
			RL	Rapeseed oil		IST	Ending intervention stocks; kt
			SFL	Sunflower oil		LI	Live inventory; head
			CSL	Cottonseed oil		MAR	Margin between wholesale and retail; national currency/unit of product

Region			Commodity			Item	
			GL	Groundnut oil		NC..CE	Net costs of biofuels production from cereals; LC per million litres
			PL	Palm oil		NC..CG	Net cost from coarse grains; national currency/hl
			SM	Soybean meal		NC..SBE	Net production cost of ethanol using SBE; national currency/kl
			RM	Rapeseed meal		NC..VL	Net production cost of biodiesel using VL; national currency/kl
			SFM	Sunflower meal		NC..WT	Net production cost of ethanol using WT; National currency/kl
			CSM	Cottonseed meal		NFS	Non-fat solid content; decimal
			GM	Groundnut meal		NQT	Out-of-quota production (sugar beet, EUN)
			EG	Eggs		NQT..EXSHR	Share of exports in out-of-quota production (sugar beet, EUN); decimal
			CK	Chicken		NT	Net trade; kt
			OP	Other poultry		OU	Other use; kt
			PT	Poultry		POP	Population; thousand
			BV	Beef and veal		PP	Producer price; national currency/t
			CN	Copra (coconut)		PP..CHN	Producer price used in the China module; national currency/t
			RY	Rye		PP..ET	Commodity price for ethanol use; LC/t
			OT	Oats		PP..EX	Export price (white sugar, EU)
			OC	Other cereals		PP..FAT	Market clearing price for milk fat; national currency/t
			WTD	Durum wheat		PP..FE	Price for feed
			AG	Total agricultural area		PP..NFS	Milk market clearing price for milk non-fat; national currency/t
			BN	Beans		PP..NQT	Domestic price with no quota (sugar beet, EUN); LC
			FP	Field peas		PP..PRAT	Quality adjustment factor; decimal
			BF	Biofuels		PP..QT	Quota price; LC
			CT	Cotton		PR..DIE	Price ratio between biodiesel and diesel, market prices; ratio
			CR	Crop		PR..GAS	Price ratio between ethanol and gasoline, market prices; ratio
			RU	Ruminants		PRST	Private ending stocks; kt
			NR	Non-ruminants		QC	Total consumption; kt
			BP	Dried beet pulp		QC..ADD	Consumption of ethanol as additive; kt

Region			Commodity			Item	
			OFP	Other dairy products containing fat solids		QC..BF	Consumption of total biofuels; kt
			ONP	Other dairy products containing non-fat solids		QC..BLD	Consumption of total blended biofuels; kt
			CRX	Annual crop not included elsewhere		QC..LBLD	Consumption of low blend biofuels; kt
			PO	Potatoes		QC..OBL	Consumption of mandated biofuels; kt
			SET	Set-aside		QCS	Consumption share; decimal
			FO	Fodder crops		QCS..CALC	Calculated consumption share (biofuels, EU); decimal
			CEB	Cereal brans		QCS..OBL	Blending obligation, share; volume basis (in the EU in energy basis)
			LPF	Low-protein feed		QCS..RES	Consumption share of waste oils for biodiesel production; decimal
			MPF	Medium-protein feed		QCS..SEC	Consumption share of second generation biofuels; decimal
			HPF	High-protein feed		QP	Production; kt
			APF	All protein feed		QP..BV	Production from cattle
			MBM	Meat and bone meal		QP..CG	Total domestic production of coarse grains; kt
			MN	Manioc		QP..CGSHR	Coarse grains share in ethanol production; decimal
			FM	Fish meal		QP..COW	Milk production from cows; kt
						QP..DY	Production from pure cow's milk; kt
						QP..ND	Production other than that from cow's milk; kt
						QP..NQT	Production underlined supply; kt
						QP..PK	Production from swine
						QP..PT	Production from poultry including feather meal
						QP..RES	Production from agricultural residues; million litres
						QP..SBE	Production from sugar beet; kt
						QP..SH	Production from swine
						QP..T	HFCS production test variable; kt
						QP..VL	Total domestic production of vegetable oil; kt
						QP..WT	Total domestic production of wheat; kt
						QPC..CE	Total domestic production capacity from cereals for biofuel production; million litres

Region			Commodity			Item	
						QPC..SBE	Ethanol production capacities using SBE; million litres
						QPC..VL	Total domestic production capacity from vegetable oil; million litres
						QPR..CE	Capacity use rate of cereals for biofuel production; decimal
						QPR..SBE	Capacity use rate; decimal
						QPR..VL	Capacity use rate; decimal
						QPS	Slaughtered production; kt
						QT	Quotas; kt
						QT..CHG	Exceptional conversion of out-of-quota sugar into in-quota-sugar (EU); kt
						RET	Average returns;;LC/ha
						RH	Returns per hectare; national currency/ha
						RH..NQT	Returns per hectare without quota (sugar beet, EU); national currency/ha
						SFP	Single farm payment factor; decimal
						SHR	Total demand to feed demand share; decimal
						SLH	Slaughtered animals; thousand head
						ST	Ending stocks; kt
						ST..CF	Stock carry-forward (sugar, EU); kt
						TAVI	Import ad-valorem tariff; %
						TRQ	Import tariff quota; kt
						TSP..OQS	Import tariff out-of-quota, scheduled; EUR/t
						VNC..CE	Variable net costs of biofuels production from cereals; LC per million litres
						VNC..CG	Variable net production cost of ethanol using CG
						VNC..SBE	Variable net production cost of ethanol using sugar beet
						VNC..VL	Variable net production cost of ethanol using vegetable oil
						VNC..WT	Variable net production cost of ethanol using wheat; LC/t
						VST	Change in stocks; kt
						XR..CHN	Exchange rate used in the China module; national currency/USD
						YLD	Yield; t/ha

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