Methodology

This section outlines the five main aspects of the methodology used to generate the *Agricultural Outlook*. First, a general description of the agricultural baseline projections and the *Outlook* report is given. Second, the compilation of a consistent set of the assumptions on macroeconomic projections is analysed in greater detail, followed by a presentation on how production costs are taken into account in the model's supply equations. Section 4presents the feed demand system that has been incorporated since the 2014 version of the model. Finally, Section 5 presents the methodology developed for the stochastic analysis conducted with the Aglink-Cosimo model.

1. The generation of the *OECD-FAO Agricultural Outlook*

The projections presented and analysed in this publication are the result of a process that brings together information from a large number of sources. The use of a model jointly developed by the OECD and FAO Secretariats, based on the OECD's Aglink model and extended by FAO's Cosimo model, facilitates consistency in this process. A large amount of expert judgement, however, is applied at various stages of the Outlook process. The *Agricultural Outlook* presents a single, unified assessment, judged by the OECD and FAO Secretariats to be plausible given the underlying assumptions, the procedure of information exchange outlined below and the information to which they had access.

The starting point of the outlook process is the reply by OECD countries (and some non-member countries) to an annual questionnaire circulated in the fall. Through these questionnaires, the OECD Secretariat obtains information from these countries on future commodity market developments and on the evolution of their agricultural policies. The starting projections for the country modules handled by the FAO Secretariat are developed through model based projections and consultations with FAO commodity specialists. External sources, such as the IMF, the World Bank and the UN, are also used to complete the view of the main economic forces determining market developments. This part of the process is aimed at creating a first insight into possible market developments and at establishing the key assumptions which condition the outlook. The main economic and policy assumptions are summarised in the Overview chapter and in specific commodity tables of the present report. The sources and assumptions for those assumptions are discussed in more detail further below.

As a next step, the modelling framework jointly developed by the OECD and FAO Secretariats is used to facilitate a consistent integration of this information and to derive an initial set of global market projections (baseline). In addition to quantities produced, consumed and traded, the baseline also includes projections for nominal prices (in local currency units) for the commodities concerned. Unless otherwise stated, prices referred to in the text are also in nominal terms. The data series for the projections are drawn from OECD and FAO databases. For the most part, information in these databases has been taken from national statistical sources. Trade data for regions, e.g. the European Union or regional aggregates of developing countries, refer only to extra regional trade. This approach results in a smaller overall trade figure than cumulated national statistics. For further details on particular series, enquiries should be directed to the OECD and FAO Secretariats.

The model provides a comprehensive dynamic economic and policy specific representation of the main temperate-zone commodities as well as rice, cotton and

vegetable oils. The Aglink and Cosimo country and regional modules are all developed by the OECD and FAO Secretariats in conjunction with country experts and, in some cases, with assistance from other national administrations. The initial baseline results for the countries under the OECD Secretariat's responsibility are compared with those obtained from the questionnaire replies and issues arising are discussed in bilateral exchanges with country experts. The initial projections for individual country and regional modules developed by the FAO Secretariat are reviewed by a wider circle of in-house and international experts. In this stage, the global projection picture emerges and refinements are made according to a consensus view of both Secretariats and external advisors. On the basis of these discussions and of updated information, a second baseline is produced. The information generated is used to prepare market assessments for biofuels, cereals, oilseeds, sugar, meats, fish and sea food, dairy products and cotton over the course of the outlook period, which is discussed at the annual meetings of the Group on Commodity Markets of the OECD *Committee for Agriculture*. Following the receipt of comments and final data revisions, a last revision is made to the baseline projections. The revised projections form the basis of a draft of the present *Agricultural Outlook* publication, which is discussed by the *Senior Management Committee* of FAO's Department of Economic and Social Development and the OECD's *Working Party on Agricultural Policies and Markets of the Committee for Agriculture*, in May 2015, prior to publication. In addition, the Outlook will be used as a basis for analysis presented to the FAO's *Committee on Commodity Problems* and its various *Intergovernmental Commodity Groups*.

The Outlook process implies that the baseline projections presented in this report are a combination of projections developed by collaborators for countries under the OECD Secretariat's responsibility and original projections for the 42 countries and regions under the FAO Secretariat's responsibility. The use of a formal modelling framework reconciles inconsistencies between individual country projections and forms a global equilibrium for all commodity markets. The review process ensures that judgement of country experts is brought to bear on the projections and related analyses. However, the final responsibility for the projections and their interpretation rests with the OECD and FAO Secretariats.

2. Sources and assumptions for the macroeconomic projections

Population estimates from the 2012 Revision of the United Nations Population Prospects database provide the population data used for all countries and regional aggregates in the *Outlook*. For the projection period, the medium variant set of estimates was selected for use from the four alternative projection variants (low, medium, high and constant fertility). The UN Population Prospects database was chosen because it represents a comprehensive source of reliable estimates which includes data for non-OECD developing countries. For consistency reasons, the same source is used for both the historical population estimates and the projection data.

The other macroeconomic series used in the Aglink-Cosimo model are real GDP, the GDP deflator, the private consumption expenditure (PCE) deflator, the Brent crude oil price (in US dollars per barrel) and exchange rates expressed as the local currency value of USD 1. Historical data for these series in OECD countries as well as Brazil, Argentina, China and Russian Federation are consistent with those published in the OECD Economic Outlook No.96, November 2014. For other economies, historical macroeconomic data were obtained from the IMF, World Economic Outlook, October 2014. Assumptions for 2015-2024 are based on the recent medium term macroeconomic projections of the OECD Economics Department, projections of the OECD Economic Outlook No. 95 and projections of the IMF.

The model uses indices for real GDP, consumer prices (PCE deflator) and producer prices (GDP deflator) which are constructed with the base year 2010 value being equal to 1. The assumption of constant real exchange rates implies that a country with higher (lower) inflation relative to the United States (as measured by the US GDP deflator) will have a depreciating (appreciating) currency and therefore an increasing (decreasing) exchange rate over the projection period, since the exchange rate is measured as the

local currency value of 1 USD. The calculation of the nominal exchange rate uses the percentage growth of the ratio "country-GDP deflator/US GDP deflator".

The oil price used to generate the *Outlook* until 2013 is taken from the short term update of the *OECD Economic Outlook* n°96 (November 2014). For 2014, the annual average daily spot price is used, while the average daily spot price for December 2014 is used as the oil price for 2015. Brent crude oil prices from 2016 are projected to grow at the same rate as projected by the *World Energy Outlook* (IEA, November 2014).

3. The representation of production costs in Aglink-Cosimo

Changes in production costs are an important variable for farmers' decisions on crop and livestock production quantities, in addition to output returns and, if applicable, policy measures.

While supply in Aglink-Cosimo is largely determined by gross returns, production costs are represented in the model in the form of a cost index used to deflate gross production revenues. In other words, supply equations in the model in most cases depend on gross returns per unit of activity (such as returns per hectare or the meat price) relative to the overall production cost level as expressed by the index. Consequently, equations for harvested areas in crop production and for livestock production quantities take the following general forms:

$$AH = f\left(\frac{RH}{CPCI}\right);\ QP = f\left(\frac{PP}{CPCI}\right)$$

with:
- AH area harvested (crop production)
- RH returns per hectare (crop production)
- CPCI commodity production cost index
- QP production quantity (livestock production)
- PP producer price (livestock production)

Among others, energy prices, increased by rising crude oil prices, have fostered attention to agricultural production costs in agricultural commodity models. Energy prices can significantly impact on international markets for agricultural products as production costs for both crops and livestock products are highly dependent on energy costs. Fuels for tractors and other machinery, as well as heating and other forms of energy are directly used in the production process. In addition, other inputs such as fertilisers and pesticides have high energy content, and costs for these inputs are driven to a significant extent by energy prices. It is therefore important to explicitly consider energy prices in the representation of production costs.

The production cost indices employed in Aglink-Cosimo for livestock products is constructed from three sub-indices representing non-tradable inputs, energy inputs, and other tradable inputs, respectively. While the non-tradable sub-index is approximated by the domestic GDP deflator, 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:

$$\begin{aligned} CPCI_{r,t} = {} & CPCS^{NT}_{r,t} * GDPD_{r,t} / GDPD_{r,bas} \\ & + CPCS^{EN}_{r,t} * \left(XP^{OIL}_{t} * XR_{r,t}\right) / \left(XP^{OIL}_{bas} * XR_{r,bas}\right) \\ & + \left(1 - CPCS^{NT,I}_{r,t} - CPCS^{EN,I}_{r,t}\right) * \left(XR_{r,t} * GDPD_{USA,t}\right) / \left(XR_{r,bas} * GDPD_{USA,bas}\right) \end{aligned}$$

with:
- CPCI commodity production cost index for livestock
- $CPCS^{NT}$ share of non-tradable input in total base commodity production costs
- $CPCS^{EN}$ share of energy in total base commodity production costs

GDPD	deflator for the gross domestic product
XP^{OIL}	world crude oil price
XR	nominal exchange rate with respect to the US Dollar
r,t	region and time index, respectively
bas	base year (2000 or 2005 or 2008) value

The production cost index is different for each *crop products* and is constructed from five sub-indices representing seeds inputs, fertiliser inputs, energy inputs, other tradable inputs and non-tradable inputs, respectively.

$$
\begin{aligned}
CPCI^{c}_{r,t} = {} & CPCS^{NT}_{r,t} * GDPD_{r,t} \,/\, GDPD_{r,bas} \\
& + CPCS^{EN}_{r,t} * \left(XP^{OIL}_{t} * XR_{r,t}\right) / \left(XP^{OIL}_{bas} * XR_{r,bas}\right) \\
& + CPCS^{FT}_{r,t} * \left(XP^{FT}_{t} * XR_{r,t}\right) / \left(XP^{FT}_{bas} * XR_{r,bas}\right) \\
& + CPCS^{TR}_{r,t} * \left(XR_{r,t} * GDPD_{USA,t}\right) / \left(XR_{r,bas} * GDPD_{USA,bas}\right) \\
& + CPCS^{SD}_{r,t} * PP^{c}_{r,t}(-1) \,/\, PP^{c}_{r,bas}
\end{aligned}
$$

with:

$CPCI^{C}$	commodity production cost index for crop product c
$CPCS^{NT}$	share of non-tradable input in total base commodity production costs
$CPCS^{EN}$	share of energy in total base commodity production costs
$CPCS^{FT}$	share of fertiliser in total base commodity production costs
$CPCS^{TR}$	share of other tradable input in total base commodity production costs
$CPCS^{SD}$	share of seeds input in total base commodity production costs
GDPD	deflator for the gross domestic product
XP^{OIL}	world crude oil price
XP^{FT}	world fertiliser price
PP^{c}	producer price for crop product c
XR	nominal exchange rate with respect to the US Dollar
c	Crop product
r,t	region and time index, respectively
bas	base year (2000 or 2005 or 2008) value

The shares of the various cost categories are country specific. They were estimated based on historic cost structures in individual countries. Shares vary depending on the development stages of the countries and regions. Developed countries tend to have higher shares of energy, fertiliser and tradable inputs than developing nations.

The fertiliser price is an index produced by the World Bank (Pink Sheets). It is formed as an index as follows:

XP^{FT} = 0.2*DAP+0.16*MOP+0.02*TSP+0.62*Urea

With:

US Diammonium Phosphate (DAP)
Canada Potassium Chloride (MOP)
Triple superphosphate (TSP)
Urea (Black Sea)

And is represented by an equation in the Aglink-Cosimo model:

$$XP_t^{FT} = CON + elas_{FT}^{lag\,1} * (XP_{t-1}^{FT} - XP_{t-2}^{FT}) + elas_{FT}^{lag\,2} * (XP_{t-2}^{FT} - XP_{t-3}^{FT}) + elas_{FT}^{OIL\,1} * (XP_{t-1}^{OIL} - XP_{t-2}^{OIL}) + elas_{FT}^{OIL\,2} * (XP_{t-2}^{OIL} - XP_{t-3}^{OIL}) + elas_{FT}^{crop\,1} * (XP_{t-1}^{crop} - XP_{t-2}^{crop}) + elas_{FT}^{crop\,2} * (XP_{t-2}^{crop} - XP_{t-3}^{crop}) + XP_{t-1}^{FT}$$

With :

$$XP_t^{crop} = 0.5 * XP_t^{CG} + 0.2 * XP_t^{WT} + 0.2 * XP_t^{OS} + 0.1 * XP_t^{RI}$$

With XP^{OIL} world crude oil price
XP^{FT} world fertiliser price
XP^{CG} world coarse grain price
XP^{WT} world wheat price
XP^{OS} world oilseed price
XP^{RI} world rice price

4. The feed demand system

A new feed demand system, the final element of the Aglink/Cosimo review, has been fully incorporated in the 2014 version of the model. That improvement insures a greater consistency between animal requirement and amount of feed consumed. To achieve this many new feeds had to be included in the model such as distiller's dry grain, corn gluten feed, dried beet pulp, cereal bran, meat, bone and feather meals, field peas, roots and tubers, fishmeal, whey powder and molasses. Complete balance sheets[1] and world market clearing price were introduced for all of these products except field peas. Fodder feeds (pasture, hay and cereal silage) are implicitly taken into account in the feed demand functions of countries endowed with these resources. The cross price demand elasticities of these products with coarse grains or protein meals are high insuring a consistent evolution of their price with their main competitor in the model.

5. The methodology of stochastic simulations with Aglink-Cosimo

The stochastic analysis can be summarised in three steps.

- For the yield drivers that are treated stochastically historical deviations around trends are calculated. For macro-economic drivers that are treated stochastically historical deviations around expected values are calculated.
- From these deviations the stochastic behaviour of the drivers is formalised and 1 000 sets of future alternative values for these drivers, based on their stochastic behaviour, are generated.
- The Aglink-Cosimo model is simulated for each of the alternative values of the generated drivers.

These steps are explained in more detail below.

Step (1): Estimating variability based on historical data

For the macroeconomic variables, deviations from expected values are computed as the ratio of the one-year-ahead forecast to the observed outcome. The forecasts come from past OECD Economic Outlooks and from the International Monetary Fund, and are

1. Fishmeal is included in the satellite fish model.

available from 2003 onwards. This generates a time series of forecast errors from 2004 to 2014. The coefficient of variation (CV) of the errors is given in Table 1.

Table 1. Macroeconomic variables treated as uncertain and the calculated CV of the one-year-ahead forecast errors (in %)

	AUS	BRA	CAN	CHN	EUN	IND	JPN	NZL	RUS	USA	WLD
Consumer Price Index (CPI)	2.0	6.9	1.4	4.8	1.7	9.9	1.7	2.6	6.6	1.2	
Gross Domestic Product Deflator (GDP)	3.8	5.6	2.2	10.2	2.4	6.9	2.0	2.5	11.4	2.2	
Gross Domestic Product (GDP)	3.8	5.6	2.2	10.2	2.4	6.9	2.0	2.5	11.4	2.2	
Exchange rate (national currency/USD)	12.6	19.6	8.2	5.2	10.3	13.5	13.6	12.5	11.7		
Crude oil price											32.4

Note: the countries are denoted as follows, (AUS) Australia, (BRA) Brazil, (CAN) Canada, (EUN) European Union, (IND) India, (JPN) Japan, (NZL) New Zealand, (USA) United States, and (WLD) World

Source: OECD and FAO Secretariats.

The deviations around expected yield are measured as the ratio of the estimated yield to the observed outcome, where the estimated yield is obtained by an OLS regression over the period 1996-2013 using the same yield equations as in Aglink-Cosimo.

Step (2): Generating 1 000 sets of alternative values of the stochastic terms that mimic this stochastic behaviour

This step is performed by the software R. Step (2) uses the deviations and errors estimated in step (1), and in step (2) the 1 000 alternative values are generated for each year of the projection period 2015-24. The assumptions underlying these steps are:

- Deviations and errors are normally distributed; however yield distributions are truncated so that deviations more extreme than that experienced during the period 1996-2013 cannot occur.
- The covariance between stochastic terms is relevant information and estimates of the covariances are calculated from the errors estimated in step (1). It is assumed that the covariances between macroeconomic drivers and yield uncertainties are zero. It is also assumed that the covariances of yield uncertainties in different regional blocks are zero (eg. yields in the EU and North America have zero covariance).
- For the macroeconomic variables, the stochastic deviation is assumed to increase over time; for the simulation of the crude oil and exchange rate stochastic terms a correction factor of 0.8 is applied. By contrast, yield uncertainty is assumed not to cumulate over time.

Table 2. Commodity yields treated as uncertain and the calculated CV (in %)

	EU		Eurasia			South America				North America			South East Asia				Others			
	E15	NMS	KAZ	UKR	RUS	ARG	BRA	PRY	URY	CAN	MEX	USA	IND	MYS	THA	VNM	AUS	CHN	IND	NZL
Wheat																				
Soft	4.4	10.7	21.3	20.6	10.1	8.1	13.4	18.4	25.6	12.8	6.1	7.0	4.1				19.3	2.9	4.1	
Durum	12.4	14.5																		
Coarse grains																				
C. Grains				12.2				15.3	12.8											
Barley	4.9	9.2				16.3				11.5							19.4			
Maize	5.6	19.5				8.3	9.0			9.2	2.1	5.9						3.5		
Oats	5.4	10.0								9.3										
Rye	9.5	9.0																		
Other cereals	6.0	8.3																		
Oilseeds																				
Oilseed			29.2	12.4				11.9												
Rape	7.3	14.0								10.1							21.1			
Soybean	9.4	22.9				12.3	7.7			16.3		6.0								
Sunflower	4.9	11.9			9.1	6.2														
Others																				
Rice	3.5											3.8	5.3		2.7	2.2		1.6	5.3	
Palm oil														7.9						
Sugarbeet	4.6	5.6			8.7							6.3						8.6		
Sugarcane						9.0	2.8					6.1	6.7		10.3		10.3	9.1	6.7	
Dairy																				
Milk																	3.0			5.3

Notes: The following abbreviations are used:

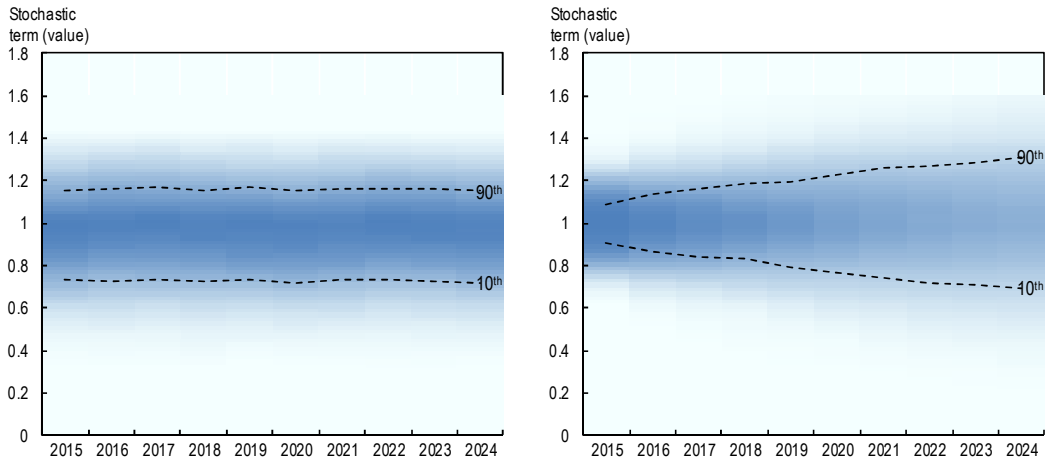
Countries: (E15) EU member states that joined before 2004, (NMS) EU member states that joined after 2004, (KAZ) Kazakhstan, (UKR) Ukraine, (RUS) Russia, (ARG) Argentina, (BRA) Brazil, (PRY) Paraguay, (URY) Uruguay, (CAN) Canada, (MEX) Mexico, (USA) United States, (IDN) Indonesia, (MYS) Malaysia, (THA) Thailand, (VNM) Viet Nam, (AUS) Australia, (CHN) China, (IND) India, and (NZL) New Zealand.

Source: OECD and FAO Secretariats.

The software generates the final stochastic terms run with these underlying assumptions. A comparison of the two panels of Figure 1 illustrates the consequences of these two approaches to simulating the stochastic terms of macroeconomic and yield variables.

Figure 1. Distribution of the multiplicative stochastic terms

Australian wheat (left figure) and Russian GDP (right figure) (2015-24)



Source: OECD and FAO Secretariats.

Step (3): Running the AGLINK-COSIMO model for each of the 1 000 alternative uncertainty scenarios

The stochastic terms are incorporated as multiplicative factors into the equations in which one of the stochastic drivers appears. This has the effect of shifting the relevant function above or below its "central" position in the deterministic baseline run. The model is run for each of the 1 000 alternative sets of stochastic drivers, providing 1 000 sets of different possible sets of the model's output variables.

For the scenarios presented, not all the 1 000 sets yield to a solution. The following table summarises the rate of success for each of the three scenarios presented in the overview chapter.

Table 3. Rate of success in the solutions for the three scenarios

Scenario	Rate of success (%)
Crop + milk yield uncertainty	97
Macroeconomic uncertainty	89
Macroeconomic + yield (crop and milk) uncertainty	90

Source: OECD and FAO Secretariats.