**Procedure to Calibrate ESIM to AGLINK Target Values**Documentation accompanying Task 1b)

# Objectives

The objective of the calibration procedure is the alignment of the ESIM baseline with the baseline produced by the AGLINK model by modifying the ESIM parameter set. This is accomplished by meeting a set of corner target values from the AGLINK baseline. More specifically, these corner targets are total use, supply, and net exports for the aggregate values of the EU 12 and EU15 regions, respectively, as well as the world prices for selected ESIM commodities.

The calibration procedure is designed to generate a set of reproducible, calibrated parameter values in an automated way.

# Approach

AGLINK target values are provided by the user in a specified format. As ESIM and AGLINK are using base data which differs due to different sources, commodity definitions and data processing, the target values for total use, supply, and world market prices are provided in percentage change terms compared to the base year. However, net exports targets are specified as quantities. Consequently, commodity market balances, i.e., the identity that net exports equal the difference between supply and demand, are generally violated when the percentage changes are applied to the ESIM base year data. Thus, the first step required is a market balancing procedure which modifies the user input data to yield quantity data which fulfills the market balance for each commodity. Afterwards, the main calibration procedure adapts certain ESIM parameters so that ESIM meets those modified AGLINK targets. Both procedures are formulated in GAMS and are run independently in succession. The outcome of the entire procedure is a set of parameters which, when used in an ESIM simulation run, reproduces the modified AGLINK targets.

The complete procedure consists of three steps:

Step 1: Read AGLINK user input data and modify the input data to construct consistent market balances (run GAMS file ‘cal\_market\_balancing.gms’).

Step 2: Generate a set of production and demand parameters for ESIM which reproduces the above consistent market balances (run GAMS file ‘esim.gms’).

Step 3: Store the original Aglink targets and the calibrated ESIM results together with some measure of deviation in a file to facilitate reporting on the calibration outcome (run GAMS file ‘cal\_comparison.gms’).

# User input data

The procedure calibrates ESIM so that the following target values are met: for selected ESIM commodities, total use, supply, and net exports for the aggregate values of the EU 12 and EU15 regions, respectively, as well as the world market prices for selected commodities. The target values are provided by the user in terms of percentage changes from the base year in all cases with the exception of net exports which are provided in terms of the traded quantity. The entire input data needs to be provided in form of an especially formatted MS Excel workbook file named “calibration\_aglink\_input.xlsx”. The first sheet of the workbook contains instructions on the required format.

A second Excel workbook named "cal\_control.xlsx" provides some options to control the calibration procedure (see Section 5.2.1).

# Market balancing procedure

Initially, the user-provided percentage change and quantity targets are modified so that the market balance identity holds for each market. To this end, the percentage change targets are translated to absolute quantities by applying the target percentage change to the corresponding base year quantity from the ESIM database. The net export quantities are taken unmodified. Besides the target values, the user input data specifies "margins of acceptance" which relax the target quantities to target intervals. This data is fed into a GAMS-based mathematical model to produce consistent market balances while minimizing the sum of the squared percentage deviations from the targets (see file "cal\_market\_balancing.gms"). The margins of acceptance are implemented as bounds on the supply, total use and net export variables. If the PARAMETER ENFORCE\_TRADEDIR(COMM) is set to 1, a further bound is added to guarantee that the direction of trade as implicit in the AGLINK net export target is preserved (the direction of trade remains free if the parameter is set to zero). Setting the PARAMETER NETEXP\_CHG to ‘no’, the NETEXP target is set to the AGLINK target level as given. If set to ‘yes’, the NETEXP target is based on the ESIM NETEXP level plus the absolute quantity *change* in the NETEXP level calculated from the AGLINK targets.

In cases of widely differing base year data or commodity definitions, the user specified target intervals might not facilitate the construction of a consistent market balance. If such cases occur, these are listed in the parameter "infeschk" after the run of the market balancing procedure ends. The procedure automatically deals with such cases by relaxing the bounds on the variables and optimizing for the "closest" possible solution, as defined by the squared percentage deviations mentioned above, while only the direction of trade is enforced (if ENFORCE\_TRADEDIR is switched on). Furthermore, the parameter “bound” can give additional insight about the cause of the infeasibility of the user-provided targets. “bound” shows the upper and lower bounds implicit in the AGLINK target data for each of supply (S), total use (D) and net exports (X) in level terms.

To improve the outcome and resolve these infeasibilities, the user should adapt the margins of acceptance and rerun the procedure. This way, the procedure can be guided to generate more satisfactory outcomes. For very broadly defined commodities or those with strongly differing definitions between ESIM and AGLINK, it should be considered to only specify supply and total use as quantity values for the net exports will probably be misleading. The procedure then automatically calculates the net export target as the difference between supply and total use in terms of ESIM quantities.

When the procedure finishes, the percentage deviations from the targets are presented in the parameter "pcdev". The absolute percentage deviation minus the margin of acceptance, i.e., the excess over the bounds is listed in the parameter "pcdevoutma". Finally, the parameter "target" contains the consistent market balances along with the other user input data and is stored in the file "aglink\_input\_balanced.gdx".

* File to run: ‘cal\_market\_balancing.gms’
* Data input file: ‘calibration\_aglink\_input.xlsx’
* Data output file: ‘aglink\_input\_balanced.gdx’

# Calibration procedure

The calibration procedure requires a modified ESIM model where new variables are introduced to adapt as calibration coefficients while corresponding target variables are held constant. To this end, variables, equations, and complementarity conditions are combined into a new model (BASELINECALIB, see file "cal\_model.gms"). The ESIM model mechanisms differ between product groups and thus calibration coefficients are introduced in different equations corresponding to the specifics of the target variable and commodity group. The details are described below, for each target variable (PW, SUPPLY, TUSE, NETEXP) separately.

The general approach is to scale demand and supply curves by changing the efficiency parameter in front of ESIM's Cobb-Douglas type supply and demand functions. This can be interpreted as technical progress in the case of supply and as market scaling or preference shifting in the case of demand functions. The model formulation differs between product groups as there are a number of special product relationships and characteristics requiring special treatment as detailed in the following subsections.

The EU AGLINK targets are specified only for the aggregate country regions EU 15 and EU 12. This requires an assumption on how to distribute the change across the individual countries of each aggregate region as they are separately identified in ESIM. In absence of country-specific information, the calibration procedure assumes that the respective functions for all countries within an aggregate region are scaled by the same parameter (coefficient). This coefficient is introduced to the function in addition to the already existing efficiency parameter so that initial country-specific differences are retained as well as those changes of that parameter which are introduced as assumptions about economic developments over time as specified in the ESIM macro data.

Technically, the model is formulated as a Mixed Complementarity Problem (MCP) which implies that the specification of equations and variables forms a fully determined equation system. Thus, assuming well-behaved functions, generally only one solution exists to this equation system with one unique set of calibrated parameters. The calibrated parameters have to be interpreted in the light of the targets and are the unique and only solution to reach those targets. "Very high” or “very low" parameter values indicate a large discrepancy of ESIM's base data and behavioral assumptions from those implicit in the AGLINK targets.

It is important to note that the calibration model has to be maintained together with the main ESIM model, i.e., each time an ESIM model equation is changed the change has to be propagated also to the calibration model ("cal\_model.gms"). Failure to follow this will invalidate the calibration procedure and the resulting parameters will not reproduce the original baseline targets when used in ESIM simulation runs.

Inputs to the calibration procedure are the file with the consistent market balance data "aglink\_input\_balanced.gdx" and the calibration control file "cal\_control.xlsx".

The main output of the calibration procedure, the set of calibrated parameters, is saved in the file "calpar.gdx". The detailed results on the target variables in absolute and percentage terms, on country and aggregate region level are stored in the file "simres.gdx".

Possible deviations from the targets are listed in the parameter "devtgt". If deviations have occurred, the procedure aborts with an error message (*after* saving the results). However, the resulting set of calibrated parameters is valid as long as the parameter "solvestat" shows the model has been solved optimally (see Section 5.2.2). Thus, the user might decide that the deviations are acceptable and to proceed with this calibrated parameter set .

Note that percentage changes for the EU12 and EU15 regions are used as targets. Since associated quantities in the ESIM database are different from those in AGLINK, when the percentage changes for EU12 and EU15 are met, this does not necessarily imply that the AGLINK percentage change for the EU27 is met. Nevertheless, as net exports are targeted in terms of quantities, the EU27 trade figures will be the sum of EU12 and EU15 figures in any case.

## Implementation of the calibration parameters

### Target variable: world market price (PW)

Note that PW only exists for traded commodities. Moreover, PW calibration is not enabled for by-products (GLUTFD, SUNMEAL, RAPMEAL, and SOYMEAL) which depend on the primary product according to a fixed input-output ratio, e.g., SOYMEAL occurs as a by-product of SOYOIL production. Calibration against a target PW is reached by scaling the supply or demand curves of the non-EU regions so that market clearing occurs at the targeted PW. Technically, this corresponds to a change of the efficiency parameter of the Cobb-Douglas type supply and demand function. The specific modeling formulation used depends on whether it is a processed commodity (i.e., the processing is explicitly modeled in ESIM) or not and how the processing itself has been modeled. All non-EU countries experience an identical relative change of their efficiency parameter.

Unprocessed commodities[[1]](#footnote-1)

This includes all primary crops and livestock products which include SUGAR and PALMOIL in ESIM. These markets are calibrated against PW by scaling the supply curve. Technically, an additional technical progress parameter (TP\_GR\_NONEU) is introduced to the supply functions of the non-EU countries and adapts to meet the target PW.

Final dairy products[[2]](#footnote-2)

In ESIM, the raw milk commodity is first split into their fat and protein components (according to fixed content coefficients) which are then recombined to produce a final dairy product like cream or cheese. An efficiency parameter (PDEM\_TR) is introduced to the ESIM equation (PROCM\_EQ) which determines total processing demand for FAT and PROTEIN from dairy processing. This parameter changes the production of a particular dairy product by changing its processing demand for FAT and PROTEIN. The parameter could be interpreted as changing the production preferences between dairy products. The corresponding parameter in the calibration model is called PDEM\_TR\_CAL.

Plant oils[[3]](#footnote-3)

Each plant oil (SOYOIL, RAPOIL, or SUNOIL) is processed from a specific input crop where input relates to output according to a constant extraction coefficient. This constellation does not allow direct introduction of a supply-side calibration parameter. Instead, calibration is facilitated by increasing the processing demand for the associated oil seed inputs. Accordingly, a calibration coefficient (PDEM\_TR\_NONEU\_OIL) is introduced to the processing demand function for oilseeds. The increase in oilseed inputs then leads to an increase in oil output and scales the supply curve. The production of plant oils yields oilseed cakes / meals (SOYMEAL, RAPMEAL, SUNMEAL) as by-products according to a fixed input-output coefficient. The output of these by-products is thus implicitly determined when calibrating for the corresponding oils.

Biofuels

Equivalently to the plant oils, biofuels depend on a downstream input commodity according to a fixed input-output ratio. In ESIM, ETHANOL is produced from CORN, CWHEAT and SUGAR while BIODIESEL is produced from SOYOIL, RAPOIL, SUNOIL and PALMOIL. The supply curve of biofuels is rotated directly by introducing a new processing demand trend coefficient (PDEM\_TR\_NONEU\_BF) to the supply function of the two fuels which determines the quantity of oil mix (as aggregated by a CES function) to be processed.

### Target variable: total use (TUSE)

Total use (demand) is calibrated to target quantity values for the aggregate country regions EU 15 and EU 12. As no further information about changes of the individual EU member states’ quantity levels is available and moreover, it is desired to retain the inherent economic structure of ESIM, the efficiency parameter of the Cobb-Douglas type demand functions is used for calibration and scaled using the same multiplier across all countries within the respective country group.

Unprocessed commodities and final processed commodities

For unprocessed commodities as well as final processed commodities, TUSE is calibrated by adapting the efficiency parameter of the human demand function (HDEM\_TR\_EU) and the one of the feed demand function (FDEM\_TR\_EU). These parameters are calibrated to an identical value within each group of European countries so that the target value for the sum of TUSE over all these countries is met. More specifically, HDEM\_TR\_EU for a product is equal for all countries within an EU country group and HDEM\_TR\_EU is equal to FDEM\_TR\_EU, i.e., the demand trend developments are assumed to be identical for human and feed demand. It was decided to use both demand functions for calibration as in some cases the share of one of the two demands in total use is so small that very large trend parameters would be necessary to meet the target TUSE quantity and could lead to the infeasibility of the model.

Feedstuff

Feedstuff (biofuel processing by-products and MANIOC, SMAIZE, FODDER, GRAS) are not intended to be calibrated as this would disturb the feed use behavior as implicit in the ESIM parameters.

Oilseeds

In order to calibrate oilseed quantities (SOYBEAN, SUNSEED) to levels independent of the respective processed oil, both feed and human demand are adapted as either is only a small fraction of the total use. The main use is for processing which is linked to oilseed input by an input-output coefficient and thus cannot be used for calibration. Thus, deviations of oilseed use not implicitly originating from oil processing will likely result in large shifters on the human and feed demand functions. Human and feed demand are shifted by the same multiplier (HDEM\_TR\_EUGRP = FDEM\_TR\_EUGRP).RAPSEED cannot be calibrated to as RAPSEED in its entirety is processed to RAPOIL and there is no human or feed demand for it.

### Target variable: supply (SUPPLY)

Crops

The supply of crops from the EU15 and EU12 country groups is calibrated to target quantities by adapting the technical progress parameter of yields (TP\_GR\_EU). Products without own EU production, such as MANIOC, cannot be calibrated.

Livestock

The supply of livestock from the EU15 and EU12 country groups is calibrated to target quantities by adapting their respective technical progress parameters (TP\_GR\_EU).

Final dairy products

In ESIM, the raw milk commodity (MILK) is first split into their fat and protein components (according to fixed content coefficients) which are then recombined to produce a final dairy product like cream or cheese. The content of fat and protein included in the different dairy products can change somewhat according to the contents’ prices and elasticities. A balance equation guarantees that all fat and protein from MILK produced is used up in the processing of final dairy products. Thus, there is no demand for MILK itself apart from the dairy processing activities. A scaling parameter (PDEM\_TR) is introduced to the ESIM equation which determines total processing demand for FAT and PROTEIN from dairy processing. This parameter changes the production of a particular dairy product by changing its processing demand for FAT and PROTEIN. The parameter could be interpreted as changing the production preferences between dairy products. The corresponding parameter in the calibration model is called PDEM\_TR\_CAL.

Plant oils

Plant oil supply is calibrated by adapting the processing demand trend parameter for the respective oil seeds (PDEM\_TR\_CAL), for example, RAPSEED demand for processing into RAPOIL is adapted to match the target figure for RAPOIL supply. Products without own EU production, such as PALMOIL, cannot be calibrated.

Biofuels

Equivalently to the vegetable oils, biofuels depend on an earlier stage commodity according to fixed input-output ratio. The supply curve for biofuels is calibrated by adapting the PDEM\_TR\_CAL processing demand parameter equivalently to the calibration of biofuels for PW targets above.

### Target variable: net exports (NETEXP)

Net exports are calibrated implicitly when supply and total use are calibrated in the EU of which the difference defines NETEXP. When supply and total use in the EU are fixed, and the world price is fixed and the supply in the rest of the world adapted accordingly, the demand in the rest of the world represents the function which will need to adapt to accommodate the given NETEXP as the NETEXP of the EU are also the negative NETEXP of the rest of the world. This uses up the last degree of freedom for the calibration of the model system.

## Running the calibration procedure

After generating consistent market balance input data as described in Section 4, its output (‘aglink\_input\_balanced.gdx’) gives the starting point for the main calibration procedure. The calibration procedure is embedded directly in the ESIM simulation code. Thus, it is started by running the GAMS file ‘esim.gms’ after modification of some switches:

* calibrateToAglink: ‘yes’ switches on the calibration procedure while ‘no’ runs a normal ESIM simulation.
* useCalibratedShifters: ‘yes’ injects the calibrated parameters from the previous calibration run into the model for a run of a normal ESIM simulation while ‘no’ runs ESIM without the calibrated parameters.

As a standard setting in the GAMS file ‘simulation.gms’, the calibration interpolates the years 2008 to 2011 as these “historic” AGLINK targets are particularly difficult to match. Note that in consequence, the simulations results for 2008 to 2011 should not be interpreted.[[4]](#footnote-4)

To calibrate ESIM, the normal switch parameter setting should be:  
 calibrateToAglink yes  
 useCalibratedShifters yes

To run a normal ESIM simulation based on the calibrated parameter values, the normal switch parameter setting should be:  
 calibrateToAglink no  
 useCalibratedShifters yes

### Controlling the calibration procedure

The Excel workbook ‘cal\_control.xlsx’ features a number of options to control the calibration procedure.

Controlling to which targets ESIM is calibrated to

First, there are three sheets (TUSE\_CS, SUPPLY\_CS, PW\_CS) which control the calibration sets for TUSE, SUPPLY and PW, i.e. entering the number ‘1’ into a particular cell for a country group and commodity switches on the calibration towards the target as specified in the consistent market balances file. For example, in sheet ‘TUSE\_CS’, setting the cell (CWHEAT,EU15) to one causes the procedure to calibrate towards the AGLINK target for CWHEAT in the EU15. Setting it to zero or leaving it empty switches the calibration off for this target. Cells market red should not be switched on.

Controlling interpolation

To speed up the calibration and simulation of ESIM, the introduction of parameter changes is split into several steps within a simulation periods. Often, this is necessary to generate a feasible solution in the first place. In the sheet ‘Simulation control’, the user can enter the number of interpolations for each simulation period. For example, entering a 5 for year 2012 will cause the simulation to run 5 times for the period from 2011 to 2012. It is important to note that the number of interpolations can only be changed for the calibration but then is kept for running ESIM simulations based on the calibrated parameters.

Shifter alerting

Using the sheet ‘Shifter alerting’, the user can define thresholds for the four different shifter categories , i.e., define when the parameters are considered ‘too large’ or ‘too small’. Those will then be reported after the simulation run in the parameter “Shifter alert”.

### Diagnostic output

After a calibration run, several parameters are reported in the ‘esim.lst’ file to give some diagnostic information on the solution obtained.

* ‘atLowerBound’: Shows certain variables which have hit a lower bound and thus can be the cause of problems with solving this calibration model.
* ‘solvestat’: Shows the model- and solver-status which occurred after each period. The values should be all equal to one, otherwise some solver problem has occurred and the corresponding solution is invalid. See the GAMS PATH solver user manual for details on the PATH solver status codes.
* ‘atQuota ‘: Lists all variables which are at their quota limit. This is usually intentional but also might hint to input data problems.
* ‘rest\_quota’ and ‘rest\_quota\_agg’: Difference between quota and supply level for single countries and country groups, respectively.
* ‘devtgt’: Shows percentage point deviations from target values, i.e., devtgt=result% - target%. Should be zero for all if the calibration succeeded.
* ‘TP\_GR\_EUGRP’, ‘TP\_GR\_NONEU’, ‘PDEM\_TR\_NONEU\_BF’, ‘PDEM\_TR\_NONEU\_OIL’, ‘HDEM\_TR\_EUGRP’, ‘FDEM\_TR\_EUGRP’, ‘PDEM\_TR\_CALGRP’: List the final calibrated parameters for the end period (usually 2020).
* ‘shifterAlert’: Displays shifter values only where they exceed the user-defined thresholds (defined in ‘cal\_control.xlsx’).

### Output files

* ‘calpar.gdx’: Includes the calibrated parameters. This is the main result of the calibration procedure.
* ‘calparinterpol.gdx’: Includes the calibrated parameters but also those of the interpolation steps within a period. This is intended only for internal use by the ESIM simulation procedure.
* ‘simres.gdx’: Includes results for the simulation variables in level and percentage change terms on country as well as on country group level. This is the output of an ESIM simulation run but is also created by the calibration procedure.

# Generating the comparison output file

Running the GAMS file ‘cal\_comparison.gms’ generates the file ‘cmpres.gdx’ with data to facilitate a comparison between the original AGLINK targets as given in the targets Excel input file ‘calibration\_aglink\_input.xlsx’ and the ESIM results. The parameter ‘cmpres’ includes level and percentage change data from ESIM results and AGLINK targets as well as the differences between those in percentage and level terms. The output file ‘cmpres.gdx’ can then be used for further data processing.

1. These include: CWHEAT, DURUM, BARLEY, CORN, RYE, OTHGRA, RICE, SUGAR, SOYBEAN, RAPSEED, SUNSEED, MANIOC, BEEF, SHEEP, PORK, POULTRY, EGGS, PALMOIL. [↑](#footnote-ref-1)
2. These include: SMP, WMP, CREAM, CONC\_MLK, ACID\_MLK, WHEY, BUTTER, CHEESE. CMILK is a non-tradable in the current database. [↑](#footnote-ref-2)
3. In ESIM, PALMOIL is an unprocessed commodity. [↑](#footnote-ref-3)
4. Setting INTERPOL2020: /yes/ applies a linear interpolation to the calibration target values from the base period up to the period set by the global variable INTERPOL\_UPTO. This serves the purpose of enabling a feasible solution and increasing the speed of the calibration procedure. [↑](#footnote-ref-4)