CGEBox in a nutshell

Wolfgang Britz, November 2021

CGEBox is a flexible and modular modelling framework for Computable General Equilibrium (CGE) building on the GTAP Data base and auxiliary data from the GTAP center, distributed with some additional open-access data. CGEBox can configure differently structured single country and global CGE models in comparative-static or recursive dynamic mode, supporting flexible aggregation by region, product, sector and factor from the GTAP Data Base. It is realized in **GAMS** such that all equations are coded in levels. It applies different approaches to speed up model solution (Britz and van der Mensbrugghe 2016) such as a filter routine to skim transactions related to tiny cost shares from the GTAP data base, variable substitutions, pre-solves over single country models and using CONOPT4 (based on Drud 1994) in parallel mode. It also supports a MCP setup, for instance, to model production or emission quotas. CGEBox comes with a **Graphical User Interface** based on GGIG (GAMS Graphical User Interface Generator, Britz 2014) which lets the user build a suitable data base, configure and run the model, and compare scenarios based on tables, graphs, maps and statistics (cf. Britz et al. 2015). It is **open source and open access**, its code and the freely available data bases feeding in the different modules can be downloaded from a SVN server[1]. A GAMS license is required for model runs plus a license to the GTAP data base for models beyond a 10 region and 10 sector size. CGEBox is currently mostly maintained by a team at the University Bonn and Roberto Roson (Unversity Venice and Loloya University Seville); Dominique van der Mensbrugghe contributes the GTAP Standard model in GAMS (van der Mensbrugghe 2018). CGEBox is fully documented (Britz 2019[2]) and peer-reviewed (Britz and van der Mensbrugghe 2018).

CGEBox departs from the GTAP Standard model (Hertel and Tsigas 1997) as coded by van der Mensbrugghe 2018 which is based on set of canonical assumptions found in most CGE models: competitive markets for products and factors; industries are modelled through representative, cost-minimizing firms with constant returns to scale and zero profits; households maximize utility under a budget constraint; revenues are obtained by selling services of primary factors; all macroeconomic identities hold. The GTAP Standard Model adds the so-called “global bank” which collects all savings globally and distributes it as investments to the regions based on expected returns to capital. Accordingly, both foreign and regional savings finance investments such that the BOT in each region is not forced to zero. Similar to the global bank, a central agent provides global transport services to bi-lateral trade flows differentiated by transport mode. Model and data base depict taxes in rich detail.

In the GTAP standard model, the so-called regional household approach collects in each region all income and distributes it to regional savings and private and public consumption, depicting a social welfare maximization problem. The alternative **myGTAP module** of CGEBox allows to introduce one or **multiple private households** which manage their factor stocks and distribute household income (from factor income after taxes, private and public transfers, remittances) to consumption, saving, private transfers to other households and remittances. The myGTAP module also introduces a

[1] https://svn1.agp.uni-bonn.de/svn/cgebox/, password and userid is *cgebox*
[2] https://www.ilr.uni-bonn.de/em/rsrch/cgebox/cgebox_GUI.pdf

separate account for the government. It supports asymmetric set-ups where the number of households can differ from region to region. Household surveys for 19 developing countries (Squarcina 2017) distributed with the model code[3] allow to flexibly define household types for these countries directly from the Graphical User Interface. The household survey data can also be used with a post-model micro-simulation extension. Alternatively, users can provide their own split shares to define households. Households can also be linked to sub-national regions in factor supply and final demand; the latter allows to depict subsistence production[4]. Adding the **GMIG** module (Walmsley et al. 2011) and data allows simulating bi-lateral global labour and population migration along with remittances, reporting both head counts and wages.

For final demand, the user has the choice between a **CDE, LES, CD or MAIDADS demand system**. For the latter, econometrically estimated parameters are available (Britz 2021); the other systems are parameterized based on the CDE parameters available with the GTAP data base. A flexible nesting approach allows introducing CES-nests under these top-level demand systems to better depict cross-price effects between closely related products such as, for instance, different types of meat. Pre-defined nests are available, for instance, for different food and feed categories, for different energy carriers and for the electricity mix if the GTAP-Power data base is used.

The default set-up based on the GTAP Standard model depicts international **trade** as a **two-stage Armington** approach where each production sector, savings as well as private and government consumption each have their own top-level nest which determines the expenditure share of the domestic and imported origin. A second nest with identical shares across all agents determines bi-lateral import shares. Alternatively, all firm demand, all demand, or private and government demand can be aggregated in the top-level nest. The Armington approach can be complemented with a Constant-Elasticity-of-Transformation (CET) function to distribute domestic supply. A heterogenous firm model a la **Melitz** with love of variety, fix cost for industry entry, fix costs on trade links, price mark-ups and thus monopolistic competition can be used instead of the Armington approach, leaving the user the choice which sectors to depict a la Melitz (cf. Yafari and Britz 2018). These options can be combined with a **MRIO** module where bi-lateral trade shares differ for intermediate, private, public and savings demand. Further, a module working at the single **tariff-line** is available (Jafari et al. 2021), while a CES function with commitment terms and an approach based on the Spatial Equilibrium, assuming no quality differentiation across importers are under development.

The default for the **production functions**, depicted by CES nests, is the GTAP Standard layout, i.e. substitution only takes place between primary factors. By changing the parameterisation, substitution between the value and the intermediate composite and inside the intermediate composite can be introduced. A **flexible nesting approach** allows introducing multiple nests which each combine primary factors, intermediates and other nests. That is for instance used to mimic the nesting of the GTAP-E (Burniaux et al. 2002) model. A similar approach can be used for factor supply, used for instance to replicate features of GTAP-AGR (Keeney and Hertel 2005).

Production and factor use decision can be depicted at **sub-regional level** for selected regions with a CET/CES approach to distribute factors besides land to the activities and source total domestic demand from the regions. Matching data for that module are shipped for 280 administrative regions across Europe but the user can also supply shares – at the minimum for output by sector - to dis-aggregate other regions.

[3] We thank the FAO for letting us use and distribute this data set with the model.
[4] This extension was developed with support of the EU Commission's Joint Research Center

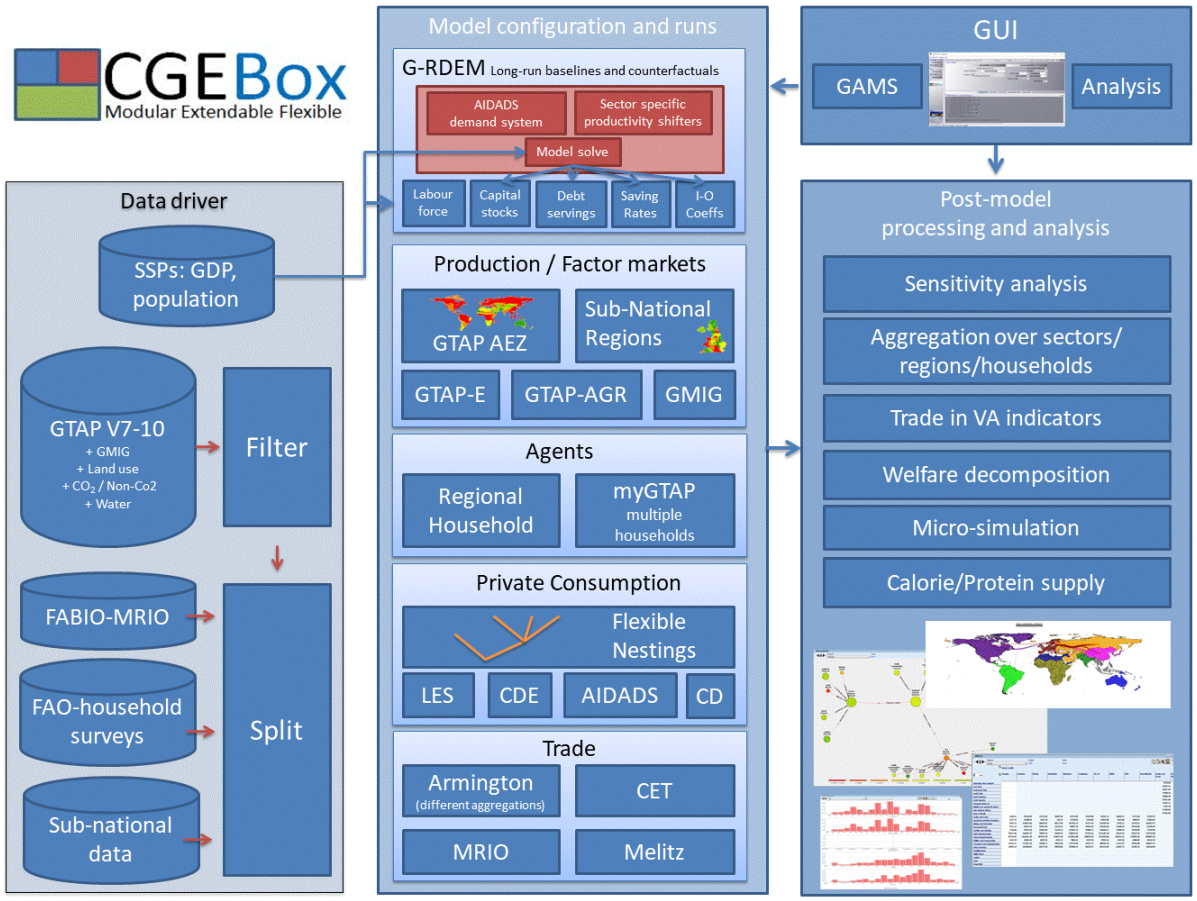
Land use can be modelled based on **GTAP-AEZ** (Lee 2005), i.e. total land in a region is divided into up to 18 so-called Agro-Ecological Zones in which a multi-level CET distributes available land in economic use to the production activities. For the top-level nests in the GTAP-AEZ module, volume-preserving CET functions are used to keep a physical land balance and to support consistent carbon stock accounting. Land supply from a land buffer can be added. The data driver and model also support the **GTAP-Water** data base (Haqiqi et al. 2016) with its distinction between irrigated and non-irrigated agriculture[5]. The carbon accounting in GTAP-AEZ complements the CO2 and non-CO2 emission (Gibbs 2014) accounting framework developed by the GTAP center which can be used in CGEBox. CGEBox can also report air pollution emissions and energy use in oil equivalents, drawing on additional data from the GTAP center.

Besides the usual capital accumulation in recursive-dynamic CGEs, the **G-RDEM** module (Britz and Roson 2019) implements features relevant for long-term baseline construction and counterfactual analysis: (1) the MAIDADS demand system mentioned above, (2) endogenous macro-saving rates, (3) sector specific productivity changes, (5) GDP per capita depending cost shares, (4) debt servings from past foreign savings. The four first features are based on econometric work, debt servings build on the global bank mechanism mentioned above. The freely available IIASA data base with projections of GDP, population by age class and education levels for the five Socio-Economic Pathways[6] is shipped ready-to-use with the G-RDEM module and can be combined with FAO projections on yields and crop land changes in baseline construction. An extension for base-line construction at the level of NUTS2 regions for Europe is under development (Britz et al. 2019b).

The **data driver** of CGEBox combines the different data bases – a GTAP data base aggregated according to the user's choice, the land use data base, CO2 and NON-CO2, data on sub-national regions, households etc. – into a mutually consistent data set with a global SAM at its core. CGEBox comes along with a split-utility based on Linear Programming to dis-aggregate the global SAM and auxiliary data to more sectors and commodities (see Britz 2021). Data from the **FABIO MRIO** (Bruckner et al. 2019) shipped with CGEBox provide the necessary data on global production, use and bi-lateral trade to split agri-food sectors in GTAP to higher detail. As the code supports non-diagonal make matrices, the split routine can also introduce multi-output activities such as oil-seed crushing to cake and oil or multiple activities producing one output, used with GTAP-WATER for irrigated and non-irrigated crop activities. Based on a special Leontief-inverse, the FABIO MRIO is also the basis to estimate on demand post-model **calorie and protein supply** of the 130 products covered by FABIO, consistent to the Food Balance Sheets of the FAO. CGEBox supports the GTAP Data base releases version 7-10.

CGEBox is a living project where new modules are added or existing ones are refined on a more or less regular basis. Care is taken that the different modules are mostly mutually compatible. This offers the user quite some freedom to structure a suitable CGE model for a specific application. CGEBox is also an open project which invites others to contribute and share.

[5] This data base was underlying the study on Food Waste by Britz et al. 2019a.
[6] http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/SSP_Scenario_Database.html


CGEBox
Modular Extendable Flexible
Data driver
SSPs: GDP, population
GTAP V7-10
+ GMIG
+ Land use
+ CO2 / Non-Co2
+ Water
Filter
FABIO-MRIO
FAO-household surveys
Split
Sub-national data
Model configuration and runs
G-RDEM Long-run baselines and counterfactuals
AIDADS demand system
Sector specific productivity shifters
Model solve
Labour force
Capital stocks
Debt servings
Saving Rates
I-O Coeffs
Production / Factor markets
GTAP AEZ
Sub-National Regions
GTAP-E
GTAP-AGR
GMIG
Agents
Regional Household
myGTAP multiple households
Private Consumption
Flexible Nestings
LES
CDE
AIDADS
CD
Trade
Armington (different aggregations)
CET
MRIO
Melitz
GUI
GAMS
Analysis
Post-model processing and analysis
Sensitivity analysis
Aggregation over sectors/ regions/households
Trade in VA indicators
Welfare decomposition
Micro-simulation
Calorie/Protein supply

References

This overview only provides some selected references which relate mostly to CGEBox itself. A more complete set of references can be found in the CGEBox model documentation.

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