An open-source version of the MANAGE model with a Graphical User Interface

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Content

Introduction

The MTI CGE group at the World Bank serves as a support and knowledge hub for CGE based macro-economic assessments at the Bank. Depending on the project, it uses either ENVISAGE (van der Mensbrugghe 2019) or CGEBox (Britz and Van der Mensbrugghe 2018) as multi-regional CGE models or MANAGE (World Bank, 2023) as a single-country one. The latter is at the focus of this paper as it comprises some interesting methodological and technical characteristics and is now open-source and open-access. Due to the medium or long-term character of economic development issues, all CGE models by the group are recursive-dynamic. They are realized in GAMS and written in levels.

ENVISAGE and CGEBox as multi-regional CGE models draw in their cores on the GTAP Standard Model (Hertel and Tsigas, 1997), and offer accordingly the so-called “Global Bank Approach” and a dis-aggregation of domestic and imported use by agent (sectors, final demanders). MANAGE instead was developed to work with single country SAMs, and does not differentiate domestic and imported use shares by agents. It complements the Armington assumption with a CET transformation function to distribute outputs to domestic sales and exports, a feature not found in the GTAP Standard model, albeit supported by ENVISAGE and CGEBox. In opposite to the standard GTAP model, MANAGE offers a detailed government account and dis-aggregates, for instance, the capital account at least to foreign borrowing to governments and foreign contributions to domestic investments. More features of MANAGE are reported below. MANAGE applications typically comprise multiple aggregate households.

While the multi-regional CGEs draw on the GTAP Data Base (Aguiar et al. 2019), MANAGE can derive SAMs from the GTAP Data Base or draw on other data sources. The latter offers potentially more up-to-date data and higher flexibility to meet client requests, for instance, with regard to sectors or institutions covered or tax detail. But constructing a SAM bottom-up from an existing IO- or SUT-table and other statistics is clearly far more labor intensive compared to starting from the GTAP Data Base. Even if the GTAP Data Base is used to construct a SAM, it needs to be complemented, for instance, by household detail or data on debt levels and related economic transaction for the typical MANAGE applications.

MANAGE applications by the World Bank currently feed into multiple later publicly available country specific so-called Climate Change Development Records (CCDRs). They are prepared with expertise from World Bank, International Finance Corporation (IFC), and Multilateral Investment Guarantee Agency (MIGA), as well as support from the International Monetary Fund (IMF). CCDRs are developed through active engagement with government counterparts, the private sector, academia, think tanks, and civil society and are firmly anchored in a country’s development goals, and backed by a CCDR data source to provide country-level climate, sectoral, and development metrics, including a breakdown of sources of current and projected GHG emissions. CGE model applications in the context of a CCDR integrate and inform sector and topic specific analytical work, for instance, with regard to energy, transport, agriculture, poverty impacts, related to Climate Change adaption and mitigation. They provide the macro-economic assessment of the developed sectoral and macro-economic strategies to reduce emissions, adapt to Climate Change and maintain economic growth and social balance. Scenarios reflect, for instance, tax or subsidy changes, investment needs or changes in future technology. The CGE models results feed in further analysis, such as in poverty assessments drawing on micro-simulation.

The many projects related to CCDRs which run in parallel under tight timelines ask for a well-organized and streamlined process of model development, maintenance and application to secure the timely delivery of salient, high-quality results. The unit has therefore launched a rigorous re-factoring of the MANAGE model with a focus on three aims: (1) a strongly data driven model set-up and a fully automated process to derive a SAM from GTAP, (2) clear identification of (optional) model features to be included in the master version, especially those relevant to the CCDRs, and (3) increased model usability. The resulting updated version of MANAGE is made open-access and open-source, not at least to increase transparency.

We gather that reporting on this process and providing some detail on the latest MANAGE version is of interest beyond the group at the World Bank for at least two reasons. First, the issues encountered when developing a new master version might be rather typical for groups working on several countries/projects with the same CGE model. Reviewing our solutions might therefore be interesting. Second, the derived open-source version of MANAGE with its automated link to the GTAP Data base might be an interesting model for single country CGE analysis, especially if time or other resources don’t allow to construct independently a SAM. Here, also the

Graphical User Interface to control model runs and its reporting part might ease single country analysis based on CGE analysis.

Data driven model set-up

MANAGE is using one single EXCEL workbook, the so-called “bridge-file”, which hosts the SAM and accompanying data (such as macro totals, population, labor force, and their forecasts) as well as behavioral and other model parameters. This workbook comprises also all sets and maps, for instance, to link sector and products to GTAP data, and to aggregate the raw single country SAM to the desired detail. This layout ensures that all necessary country specific inputs can be shipped with one file which eases the collaboration inside the team, but also with clients. The file is rigorously organized, and existing examples for countries can be used to quickly provide a data base and model parameterization for another one. An important feature are that default values or nestings can be defined and applied for all sectors, commodities and agents, such that solely exceptions from the default need to explicitly added by the analyst.

Working with GTAP data

In order to allow a fast set-up of a MANAGE application for a country available in the GTAP Data Base, a driver program can produce from the GTAP data Base a single country SAM in MANAGE format. This driver program adds data on international debt. It also adds data on domestic debt, based on available statistics or on assumptions provided by the analysist. During benchmarking using such a SAM, matching CO2 and non-CO2 emissions factors will be added, along with data on population by age and gender, including projections from UN (UNDESA, 2023). GDP projections are available from the unit’s macro-economic model MFMOD (Burns et al. 2019) and are added as well. Jointly, this provides the core data necessary for a medium to long-term MANAGE application with one aggregated household. The step to work with GTAP data is completely automated, the screen shot below shows that the analyst solely needs to provide the name of the GTAP region to derive a ready-to-use input file in EXCEL format for the SAM balancing step and from there constructing a long-run time baseline. To keep the code repository well organized, all country specific data and shock files are stored in separate sub-directories.

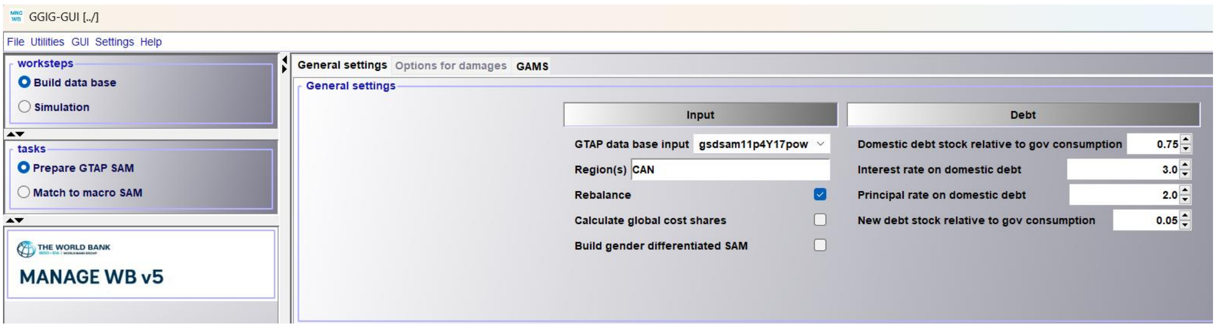

Figure 1: Screen shot of interface to produce a starting SAM and complementary data for MANAGE from a global GTAP SAM

SAM balancing, updating to macro totals and dis-aggregation

Updating to macro totals and balancing

The next steps in the data flow (see for an overview Figure 2) after a SAM is available consists in an update of the so-called proto-SAM to macro totals, the subsequent balancing of the proto-SAM and, potentially, a final dis-aggregation step. These steps are only executed as a test for a GTAP derived SAM. They don’t change any data in this case as the GTAP data provides already a balanced SAM with the full detail of the GTAP Power Data Base. Updates to macro-totals such as GDP are also currently not considered for GTAP based SAMs. Instead, the baseline for a GTAP derived country data set starts from 2017 and will use observed GDP and population changes for the first years of the baseline.

In case that a SAM is manually constructed, the updating and balancing step is an exercise typically repeated multiple times where data are manually updated between applications until an appropriate quality of the SAM is achieved. Various statistics and reports which, for instance, compare balanced to unbalanced SAM entries support the analyst in their assessment and updating of target values for the balancing step.

As a start of the manual construction work, the analysist typically collects both data for a rather aggregated Macro SAM and for a proto-SAM. The aggregated Macro SAM requires far less data and is therefore less subject to a statistic time gap. It is therefore typically more up-to-date compared to the more dis-aggregated proto-SAM, where detail reflect mostly the data availability in national IO/SUT tables or other statistics. The proto-SAM is typically further dis-aggregated by the analysist in a subsequent step as discussed below. The analysist introduces the Macro-SAM, the proto-SAM and their mappings in an EXCEL workbook (which is automatically generated for the GTAP case), and defines there as well sets for the activities, products, institutions etc.. This analyst will also add further information, such as split shares for a potential further dis-aggregation step or maps to GTAP products and sectors to derive split shares automatically. Existing workbooks for different countries can be used as templates when starting the work for a new country, in case the country is not yet covered by GTAP or the use of GTAP is not considered, for instance, when the IO table underlying the GTAP data is rather old.

Based on the Macro-SAM and its mappings to the accounts of the proto-SAM, the GAMS code will then update blocks of cells of the proto-SAM with the same factor such that they match in sum a specific cell of the Macro-SAM. This updating step is likely to introduce imbalances such that the proto-SAM used in this step does not need to be balanced.

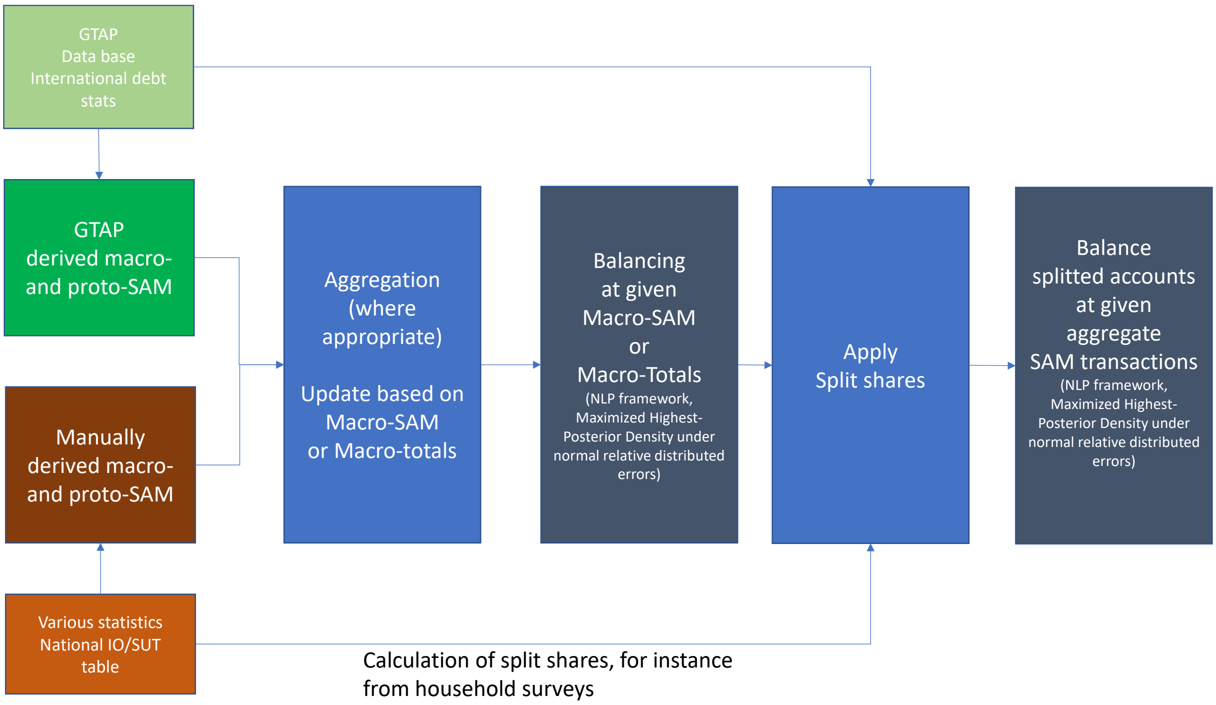

Figure 2: Overview in SAM constructing, updating, balancing and the split process

A Highest Posterior Based estimator is chosen for the consequent balancing step due its methodological and algorithmic advantages (see Britz 2021). Most cost and expenditure shares are targeted as shares during balancing and not in absolute terms. The Macro-SAM or Macro totals (such as GDP) act as constraints during the balancing step. The column and row totals can be targeted on demand. The user can add fixed target values for specific SAM cells in a separate sheet of the EXCEL-work book. This option is often used, for instance, to make sure that debt related transactions are exactly recovered. Currently, solely the equality of row and column sums is comprised in the balancing framework besides the adding up to the Macro SAM or macro total. This is likely to change in the near future, as new constraints are likely to be added, such as inequalities which ensure that ad-valorem tax rates stay in a reasonable range.

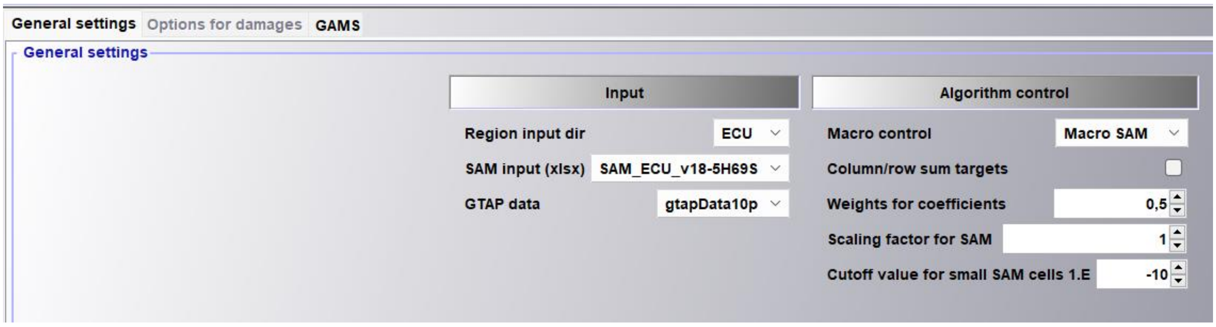

Figure 3: Screen shot of interface to of the work-step to balance and dis-aggregate the SAM

Dis-aggregation

The proto-SAM is defined mostly at the level of detail of an available IO/SUT table and might not yet provide all necessary detail for a specific analysis, such as power generation detail in carbon mitigation studies. In this case, the code supports a further dis-aggregation and sub-sequent balancing step. This final step solely relates to accounts to split. Separating the dis-aggregation step from the full SAM balancing increases transparency and control of the process of constructing the SAM.

One more or less standard case of dis-aggregation refers to multiple households. The necessary detailed data are typically introduced based on a collaboration with the poverty team at the World Bank, who will process and aggregate household surveys to provide the necessary data to split final demand, income flows etc. of the SAM. If more product or sector detail as required is found in the proto-SAM, mappings to GTAP can be provided in the EXCEL workbook and the code will derive automatically split factors.

After split shares are defined, the dis-aggregation is finalized by a separate balancing step. As usual, the more aggregated SAM cell to dis-aggregate are taken as given and fixed in this step. The balancing problems minimizes the squared relative differences to the targets derived from the split-factors and related aggregated SAM entries. Compared to e.g. Britz 202,2 the dis-aggregation framework comprises solely the most basic constraints, i.e. adding up to the given totals and equality of row and column sums for the dis-aggregated accounts.

The MANAGE CGE

Overview

The data constructed above serves as input into the MANAGE single country CGE model. MANAGE shares core assumptions with most other CGEs. All markets are competitive, final demanders (households, government, investors) maximize utility respectively revenues while firms minimize costs subject to return-to-scale technologies. This also implies that total supply by each sector is determined by the interactions of factor and product/service markets and not by firms themselves. Agents have no money illusion and are not forward looking. An enterprise account can collect shares of primary factor returns and be subject to direct taxation. Enterprises redistribute their after-tax income to savings and transfers. MANAGE comprises a rich set of tax instruments and related shifters as detailed below. Equally, debt stocks, interest and principal payments are depicted by MANAGE, under endogenous saving rates, endogenous allocation of savings to new government debt and investments, driven by endogenous returns to capital and interest rates. As this of special relevance for the applications at the bank, the related mechanisms are described in a separate brief section. MANAGE depicts Climate Change (CC) and air emissions at the detail available in the GTAP data base, and various channels to include CC related damages along with a ready-to-use data base with CC damages.

As a single country CGE, import or export prices in MANAGE are either fixed or driven by iso-elastic functions. Different closures for foreign savings are supported. The model can additionally consider transfers between the Rest-of-the-World and the institutions in the models and government debt related flows with the Rest-of-the-World (net debt, interest payments, principal) which jointly define the balance of payment.

Parameter and data are strictly separated from any code in MANAGE. Details with regard to sectors, products, to a large degree also for taxes and subsidies, as well as the demand and production function nesting are flexibly and almost entirely data driven, as detailed in the EXCEL work book called the “bridge file” which is constructed in the steps discussed above. The GAMS code of MANAGE comprises a larger set of tests which ensure that all necessary data and parameters are provided, and checks for logical coherence, for instance, in the defined nestings for the production and demand functions.

Modular master version

Motivation

Previous projects with MANAGE developed a wider range of interesting model extensions, often in parallel. Projects last for longer times. It is often impossible to change the model layout in the course of a project, for instance, once the Business-as-usual baseline is scrutinized in detail and agreed upon with all teams involved, and work on counterfactuals is going on. This often implies that methodological and code development advances in parallel in other projects, some of them devoted explicitly to model improvement.

Re-integration of code developments done in parallel into a common master is clearly challenging. It requires first a thorough analysis of differences between the model versions in use. This process is strongly helped by the consequent application of a software version system and regular group meetings where new features are presented and discussed. It also benefits from a clear grouping of model equations and related benchmarking code, such as relating to the production function, final demand, trade, taxation etc.. This clearly structured block structure helps to quickly locate where updates have been made when integrating improved features into the master version. New extensions developed in projects are typically added as modules on demand to the core model, at least until there are fully tested and all on-going projects can integrate them into their analysis. The modular structure of MANAGE therefore is also key to support the parallel use of the model in several projects while its development continues. Modularity clearly not only helps in model development, but also gives flexibility to set-up the model for specific application. Not at least, it allows to switch off module in applications, for instance, when emission accounting is not necessarily needed for an analysis and providing the necessary data would be labor intensive.

The following brief sections discuss the more non-standard features for a single country CGE model currently comprised in the open-source master version of MANAGE. Some these features can be chosen on demand as seen from the following screen shot. Most options need already to be chosen when the baseline is constructed as they influence the benchmarking of the model and can therefore not changed later in counterfactuals without repeating the baseline construction again.

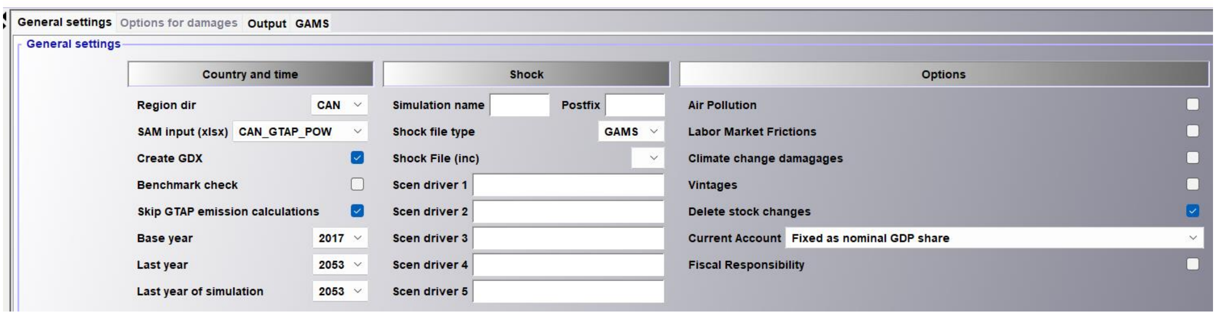

Figure 4: Screen shot of interface for baseline construction

Flexible nesting of the production function and of final demand

In opposite to many other CGE models, the code of MANAGE does not differentiate between primary factor, intermediates or bundle of factors in the definition of the production function. Instead, its code supports a completely flexible combination of intermediate and primary factors into bundles to define a CES-based multi-layer production function. On the total list of factors on which the related equations work, sub-sets are defined such as for intermediates, factors and bundles to map them to other modules of the model, such as to commodity or factor markets, or emission accounting. For each factor-activity combination, a set of efficiency shifter variables is available, for instance, by factor, by activity, by vintage, by group of sectors and some more, including related to Climate Change damages.

The model also comprises equations for so-called "twists" which allow to shift share parameters inside any CES bundle without provoking an efficient shift at the level of the bundle to support specific closure swaps. Jointly, this gives very high flexibility in defining activity specific production functions and related shifters.

The definition of the production function nesting is based on a table in the so-called bridge-file to provide a transparent and easy-to-use way to check and change the nesting structure (see Figure 5). The table also supports distributing a product, factor or bundle in shares to other bundles. For instance, part of the land could be defined as a substitute to water and the remainder as a substitute for yield increasing inputs, such that total land demand of an activity would be driven by two nests in the model.

	labus	labsk	cap_natlres	cap_labSk	ener	gas_gdt	ener_gasoil	ener_fossil	ely_tnd	cap_ener	wtr_land	va	crops	anim_meat	nd	f-top
c-gas						1										
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c-b_t															1	
c-tex															1	
c-wap															1	
c-lea															1	
c-lum															1	

Figure 5: Defining the production function nesting in a table in EXCEL

A similar approach to what is discussed for the production function is used to define a multi-layered structure of CES-demand nest under the top-level aggregated CDE demand function. When GTAP data are used, the expansion and substitution elasticities at the level of individual commodities are aggregated to the desired top-level demand aggregates automatically and introduced in the bridge-file.

The code of MANAGE supports for all product and bundles related CES and CET function the use of the additive variants (Van der Mensbrugghe and Peters 2016) to maintain physical aggregation which is considered important, for instance, in case of bundling energy carriers.

Taxes

Similar to GTAP, MANAGE covers a rich sets of ad-valorem tax instruments related to production, factor use, commodity use, emissions, imports, exports, sales, personal and corporate income taxes. For each of these, additive and multiplicative shifter variable are available, by year, by product/agent/factor/node where applicable, to flexibly define closure swaps, for instance to depict tax recycling.

Investments, saving and debt

In many studies with MANAGE, reporting on and/or controlling government deficits and debt levels is at the core of a project. Besides using well-developed tax shifters, a module depicts the relations between savings, investments and government financing. In most cases, portfolio choice is based on additive CET based revenue maximization. For households, the marginal saving rate can be rendered endogenous depending on the returns to savings and the CPI. Savings of enterprises and households are combined into a common domestic fund which is managed by a virtual portfolio manager who distributes the fund to finance investments or to buy newly issued government bonds, depending on the relation between expected returns to capital and the interest on government bonds. The interest rate is endogenous and determined implicitly by the government deficit. A virtual Rest-of-the-World investor buys government bonds depending on an iso-elastic function of the interest rates and a risk premium which depends on the debt-to-GDP ratio.

Related financial flows are depicted in detail: contribution to new debt by the different institutions, as well as principal and interest payments on the past domestic and foreign debt stock. Debt stock levels are updated in the next years based on the flows.

Climate Change related emissions, air emissions and Climate Change damages

Many MANAGE applications relate to Climate Change mitigation, adaptation or assessment of Climate Change damages. To support this, MANAGE comprises specific modelling mechanisms. As many other CGE models, MANAGE quantifies economy wide Climate Change related emissions by attaching emission factors to intermediate and final commodity demand and to factor use of firms. The emission factors are currently derived from the GTAP emission CO2 and non-CO2 emission accounting data. The model comprises shift factors which are zero by default to change exogenously or endogenously the emissions factors. This is important, for instance, to consider the combination of gas-powered electricity generation with carbon capture or other changes in technology which impact emissions factors without being explicitly modeled in the CGE. Besides defining the total emissions, MANAGE can define emission sub-inventories in a flexible manner, which can be used for reporting or targeted in closure swaps.

In order to ease to integration of Climate Change damages, a set of shifter variables is present which target productivity of production factors (primary factors, commodities or bundles thereof) or of stocks (for instance, land, capital, labor, or population). The data base by Roson and Sartori 2016 can be used to define damage channels if no detailed assessment is available. From the given changes for labor productivity, land stock, tourism demands and household energy demands at certain temperature changes, cubic functions for each region had been estimated such that also impacts of temperature changes not found in the data base by Roson and Sartori 2016 can be simulated.

Benchmarking

As in most other CGE models, benchmarking of MANAGE is completely automated and integrated in the construction of the baseline. The benchmarking initializes all variables for the full simulation horizon from the SAM and additional data. It fixes the various tax, preference and technology shifters to zero or unity, depending on how they are integrated in the equation system. For the CES and CET function comprised in the model, share parameters are derived from given prices, quantities and substitution respectively transformation elasticities. An NLP optimization problem, solved for each household separately, calibrates the expansion and substitution parameters of the CDE demand system at benchmark budget shares against user supplied income and own price elasticities. In case of a data set based on GTAP data, this is a kind of sanity check: the targeted elasticities are derived from the given parameters in the GTAP data base, such that the calibration step will recover them from the given data and elasticities.

Baseline construction and model solving

The application of MANAGE as a recursive-dynamic model starts with the construction of a baseline where at least GDP growth is exogenous. The endogenously updated shifters are then turned exogenous in subsequent counterfactuals.

Baseline construction is often quite evolved and supported by ready-to-use shock files to (1) swap GDP growth with labor productivity, (2) superimpose a electricity generation mix, which is preferred option to integrate findings from an energy system model into a baseline or counterfactuals, (2) exogenize labor stock developments by skill and gender, (3) fixing share of sectoral aggregates on value added to given projections, (4) integrate exogenous projections on energy saving technical progress or the composition of transport demand, (5) render carbon taxes endogenous under emission ceilings.

It is not uncommon that non-square model instances result when equations are added in a shock file by the analyst or the core model is under development. In case of such errors, a full pairing of the model where each equation is associated to a variable can help as GAMS will then report on non-paired variables and equations when the model is solved as a Mixed-Complementarity Problem (MCP). Therefore, all equations in MANAGE are paired such that it can be easily solved as a MCP. The core model does solely comprise equalities such the use of a MCP solver is not necessary. As solution as a Constrained System of Non-Linear Equations (CNS) is often faster and numerically more stable, solving as a CNS is the usual option chosen by analysts.

Baseline construction with many targeted variables such that different shifters, share twists, taxes etc. are simultaneously endogenous can be numerically challenging and the solver might fail to find a solution on a first trial. The code therefore comprises block of statements which reset after an unsuccessful solve variables back to previous year levels (or shares thereof) and try a restart. After repeated failed attempts as a CNS, the model is solved as a Non-Linear Optimization problem (NLP) with a dummy objective. This has proven to help in some of such cases if CONOPT is used as the solver. If PATH is used to solve the model as an MCP, different option files are tried automatically.

To ease model solution further, the code can derive automatically a factor from the SAM to scale all quantity and values in the model. This has proven especially useful in case of SAMs derived from the GTAP data base for smaller countries. Equally, all equations can be scaled on demand. The default settings on the interface typically already guarantee a successful baseline generation with fixed GDP projections for any GTAP region with the full resolution of the GTAP Power Data Base. During baseline construction, last year's solution levels of the endogenous variables serve as the starting points for the next year, with quantities and values shifted by the targeted GDP growth.

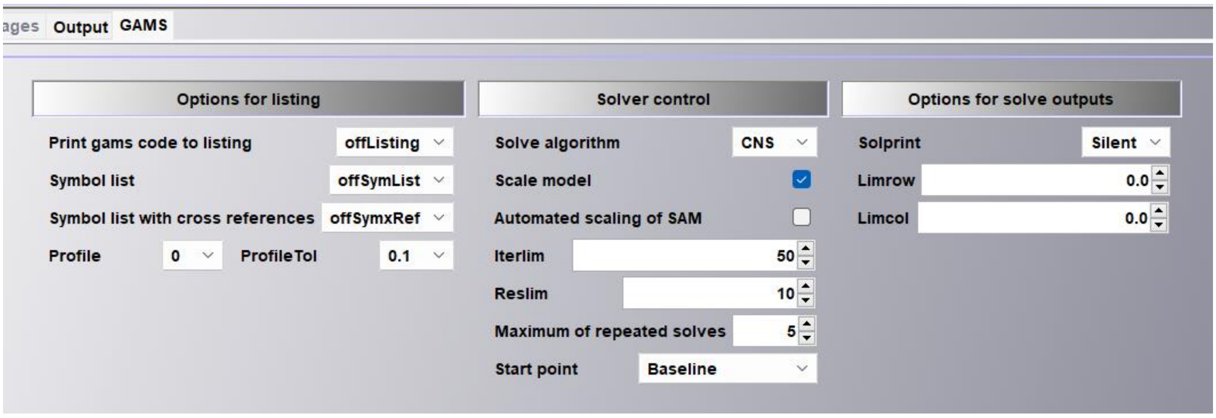

Figure 6: Screen shot of interface option to steer solution process

Figure 7 gives a technical overview on the baseline construction process. First, the different options on the interface are converted by the interface code into a run specific include file ("fromGuiToRun.inc") in GAMS format which is processed by the MANAGE code in "opt.inc". The user selects on the interface, as shown above, the EXCEL bridge-file to read. As stated above, it comprises the SAM, other data needed, parameters such as substitution and transformation elasticities, set sets of activities, products, institutions etc.. It is converted by GAMS into a GDX container ("base.inc" plus a case specific add-on on demand "load_base.inc"), and mapped to the model's set and parameter. Based on the definition of model variables and equations in "model.inc", "inical.inc" initializes the variables and derives parameters required for benchmarking. It also estimates the expansion and substitution parameters for the CDE demand system from user supplied income and own-price elasticities. The user also selects a shock file ("%shk_file%.inc") from the region-specific directory.

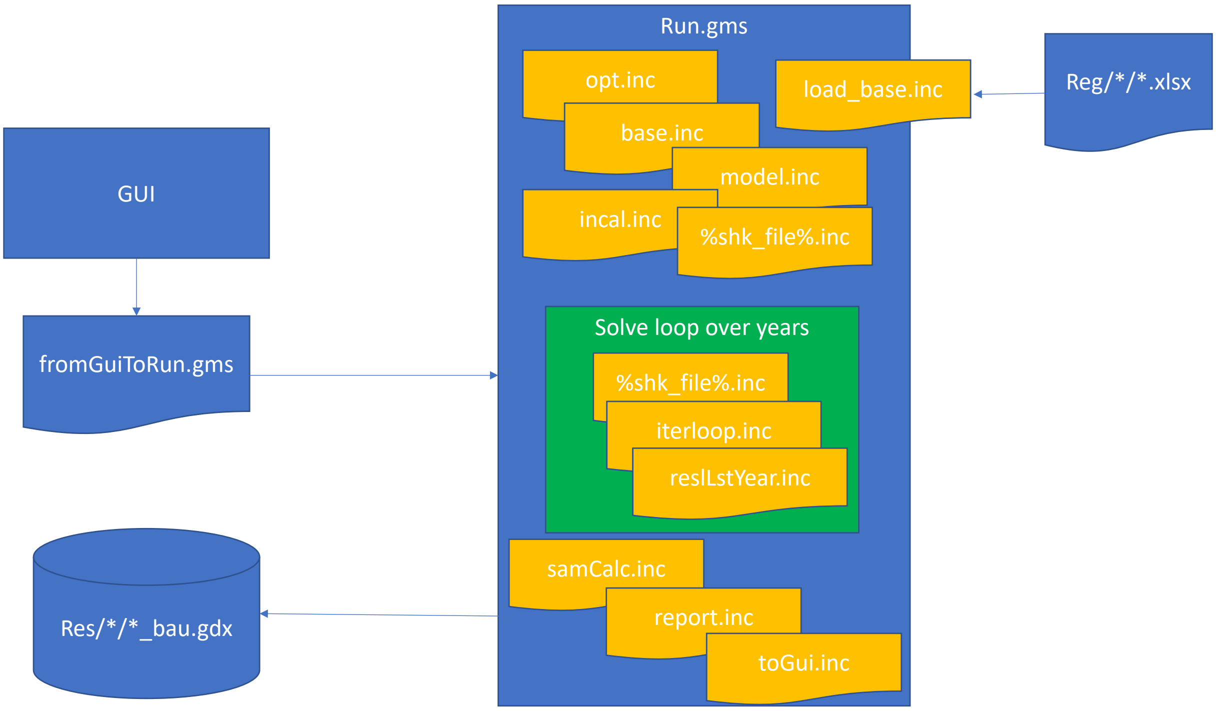

Figure 7: Overview on baseline construction

Based on this information, the code prepares the model for each year in “iterloop.inc”, which includes reading year specific shocks and from the user provided shock file. Non-fixed variables for the current year are initialized from previous year’s results in “resLstYear.inc” on demand. Once all years are solved, different options for post-model reporting can be chosen to be executed such as constructing a SAM for each year in “samCalc.inc”. The demanded results are then stored in GDX container which can also be used in the reporting back-end as detailed below.

Counterfactuals

Counterfactuals start from a given baseline. To ease this process, a GDX container is constructed at the end of a baseline run which comprises all necessary data and parameters, as well the levels of all model variables. Due to this, an existing baseline can also be easily shared with other model users via the GDX container as it encapsulates all necessary information.

Shocks are usually introduced via a GAMS file which is selected on the interface. Such a shock file can also define additional or alternative equations to be added to the model. This option is frequently used during baseline construction or in counterfactuals when variables are targeted for which not yet a default closure swap equation is defined in the core model.

As an alternative of using a GAMS based shock file, for a limited set of variables often used in shocks, an EXCEL file is automatically prepared by the baseline run. A less experienced user can overwrite exogenous variables in the EXCEL file, such as tax rates, to easily run counterfactuals. It is even possible to fix endogenous variables such as emissions for which at least one potential closure swap is pre-defined in the code and made available in the EXCEL sheet. The option to define shocks based on an EXCEL file is mostly developed for training where participants have not yet experience with GAMS.

In order to ease the work with template shock file, so called “scenario drivers” can be defined on the interface. Take the example of a shock file which renders emissions exogenous to define endogenously a carbon tax. The coder can used in the shock file so-called GAMS globals, for instance one called *emissionCeiling*. This global then fixes emissions relative to benchmark emissions (*emis.fx(t) = emis.l(t0) * %emissionCeiling%*). Different mitigation scenarios can then be run without changes in the GAMS code by entering, for instance, $setglobal emissionCeiling 0.25 in one of the scenario driver fields. This passes the information via the generated include file to the shock file.

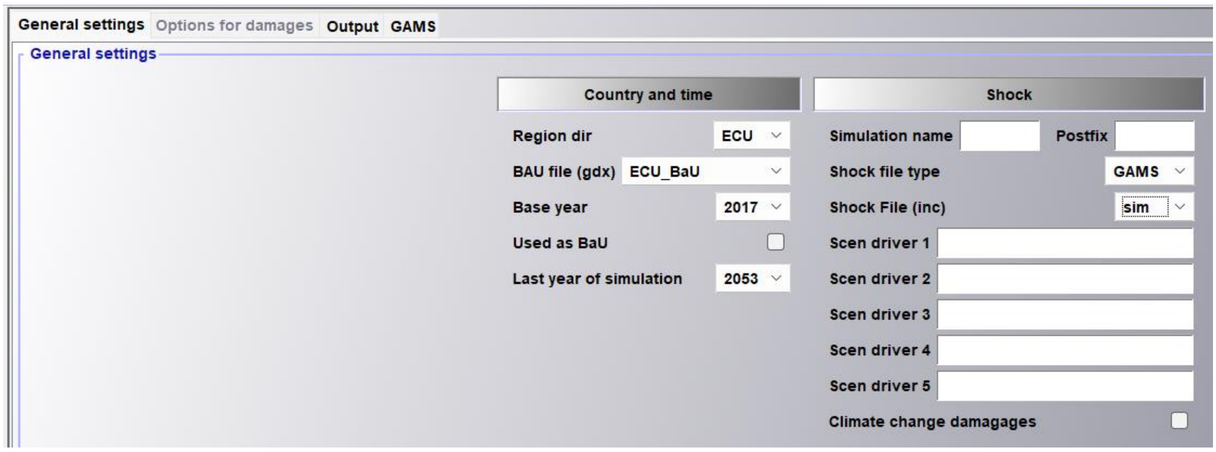

Figure 8: Screen shot of interface for baseline construction

A counterfactual run is very similar to a baseline generation. The main difference is that parameters, sets etc. are read from a GDX container constructed from the baseline such that most of the data input and all benchmarking code is skipped. Instead of initialization of variables from last year’s results, the user can also use the baseline results as starting points during counterfactuals.

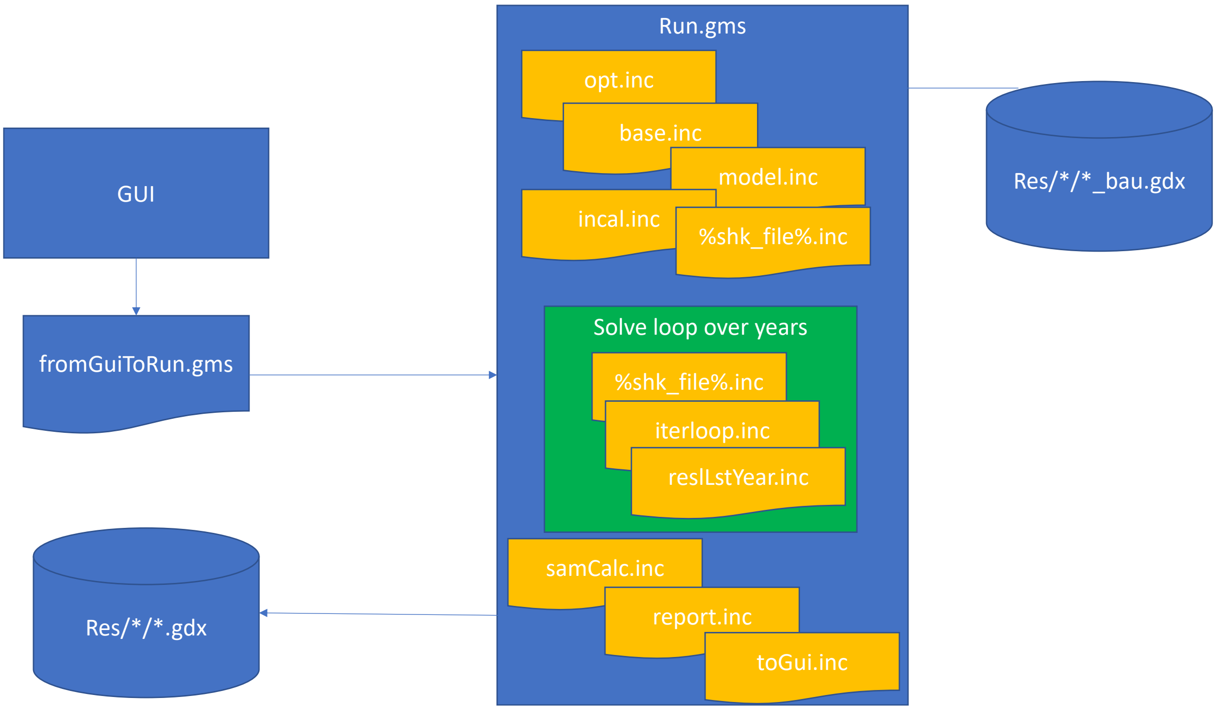

Figure 9: Overview on counterfactuals

Stochastic extension

Recently, a stochastic extension for MANAGE has been developed with the aim to also support the assessment of CC damages beyond the used of so-called "Expected Annual Damages" (EAD). The EAD of events such as floods are often relatively small in terms of macro-economic impacts, in stark contrast to the impact of a hundredth-year event such as a catastrophic flood. Assessing such more unlikely events is a challenging exercise in a recursive-dynamic setting where not only the size of the damage matters, which is related to its probability, but also potentially the frequency of more unlikely events. Two catastrophic floods just two or three years apart have potentially different long-run economic consequences compared to such events occurring multiple decades after each other.

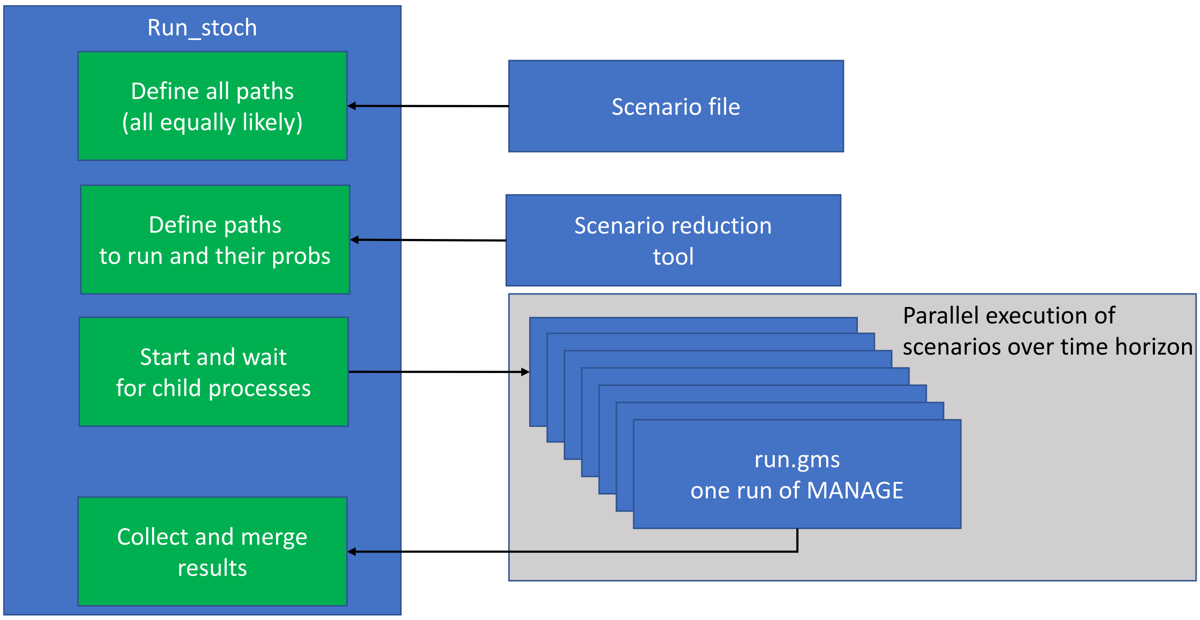

Figure 10: Overview on stochastic simulations in MANAGE

Capturing the underlying distributions with Monte-Carlo analysis given the run-time of an evolved CGE over multiple decades is numerically challenges. The stochastic extension of MANAGE therefore combines scenario reduction (Heitsch and Römisch 2009) with parallel execution of multiple CGE model runs. First, several thousand draws of damages for different return periods are drawn, using the usual trapezoidal interpolation in damage related work to derive damages for probabilities where no data are available. The scenario tree reduction bundles then time series with similar realization of the damages to a number of desired stochastic runs with the model. These runs are not necessary equally likely. Blocks of these runs are executed in parallel until all runs all solved. The results are afterwards combined into one large result set for analysis, for instance, to derive the standard deviation of impacts or other statistics of interest. Template shock files ease to introduce information for specific damages in tabular formats, such that solely the level of shocks for certain returns periods needs to be quantified by the analyst.

The interface for the stochastic runs comprises besides the option for a deterministic counterfactual also options specific to stochastic runs, such as the number of runs to perform, how many stochastic draws are made for each year and run to summarize, and how many CGE solves are allowed in parallel. For the example below, the model would solve for 35 years and perform 40 runs constructed from drawing 100 Monte-Carlos in average for one run and year, i.e. it would summarize 35x40x100 = 140.000 random variables in the scenario design.

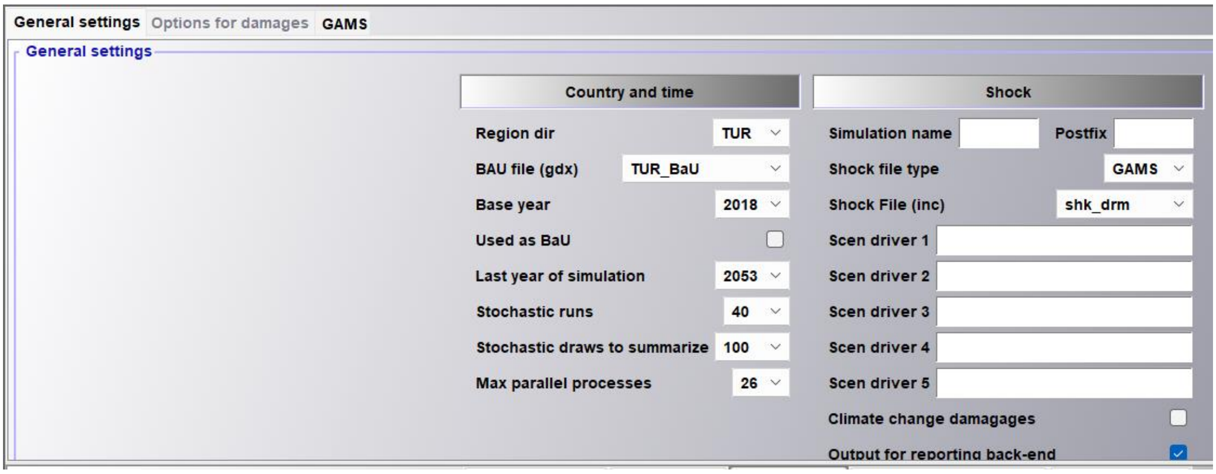

Figure 11: Screen shot of interface for stochastic runs

Graphical User Interface and post-model reporting

In order to increase usability, a Graphical User Interface (GUI) drawing on GGIG (Britz 2014) was added to the MANAGE code. It serves two main aims. First, users can configure the model set-up and model runs (data base and shock file selection, time horizon, model features etc.) via a modern Windows-style interface. Screen shots above show examples. Second, based on the GUI, users explore results based on a set of pre-defined reports (tables, graphics, see also Britz et al. 2015) which can be interactively adjusted. The reporting tool combines results from multiple scenarios in its reports, and allows to flexibly compare against the base year or a specific scenario, showing relative or absolute changes, growth rates etc.. The underlying package GGIG is used with different other economic models, including CGEBox.

Previous MANAGE projects have spent considerable amounts of time to produce tables and graphs from intermediate results to share with other teams. Now, key reports are automatically produced by the GUI to be shared with clients. The concept of the reporting back-end can be summarized by the following point. Each report combines a block of information helping to analyze the model. This often implies looking simultaneously at different model variables, say quantities, pre- and post-tax prices or values, which is cumbersome with the model listing or GAMS Studio. The back-end therefore removes the technical dis-aggregation of the model's solution space into GAMS variables, parameters and equations. The reports are defined in a relatively simple XML dialect such that analyst can also add new ones or modify existing ones. Some reports currently derived from the model solutions relate to more aggregate national accounts: macro totals such as GDP, BOT etc.; accounts for government, household, savings, enterprise (income and expenditure flows); some key household indicators (population, CPI, real income and expenditures, money metric); tax income composition; capital stock and depreciation; savings composition; debt; Demography. Other blocks of reports relate to sectors: costs (intermediates, factors, factor taxes), cost shares, tech nests, tech nests as cost shares, make matrix; households: detailed expenditures, product demands, budget shares, detailed income composition; government: consumption, income flows; taxes: product, factor, sector related; markets: factor markets, Output/exports/domestic sales/imports/market appearances, demand at agent prices, Armington decomposition w/wo margins; air emission, emission inventories, GHG emissions; and report on model diagnostics. The reports are either shown as tables or graphs, and can copy-and-pasted to spread-sheet or word-processing software. Blocks of reports can be also saved to sheets of an EXCEL workbook in an automated way.

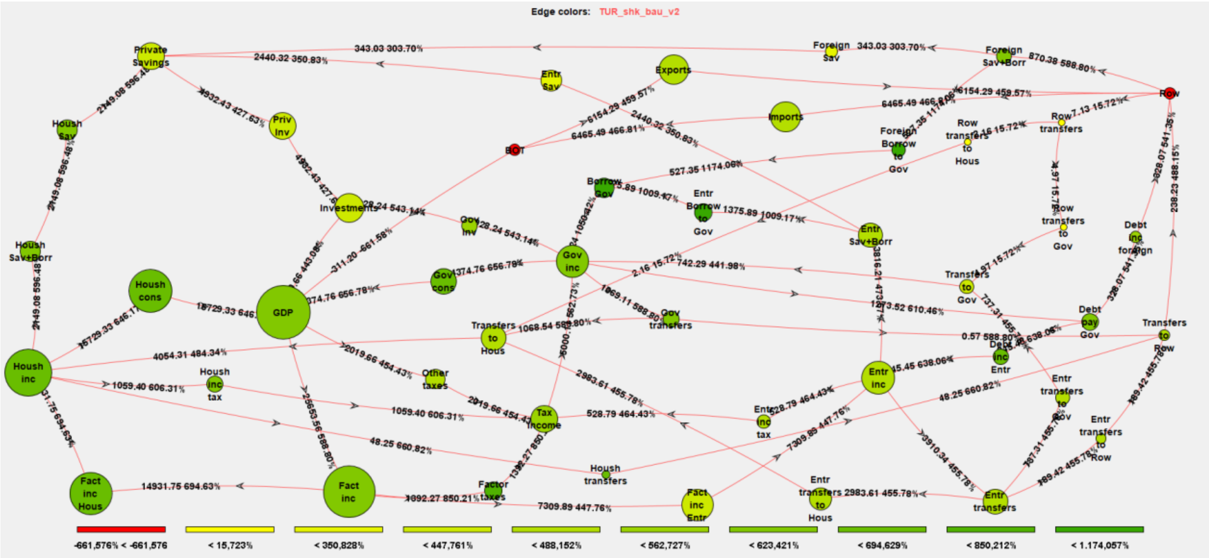

Figure 12: Screen shot of a more unusual graphic as one of the reports found in the reporting part

Another feature of the GUI is the so-called batch mode where instead of using the interface to change controls manually, control settings are stored in a text file. Such a file can comprise settings for different work steps (building the data base, baseline construction, multiple counterfactuals). The batch mode supports loop and if-statements such that, for instance, counterfactuals with step-wise changes in certain shocks can be defined. The use of the batch mode is eased by the fact that the generated include files comprise lines (which are comments from the view of GAMS) which show the (non-default) settings in use in the format required for the batch mode. The batch mode produces automatically a HTML page which reports on the different runs (settings in use, return code from GAMS) and stores the listing files for each run. To give an example: in order to test the derivation of SAMs from GTAP, a batch file constructs Sa AM for a country, checks it with the SAM balancing step of MANAGE and then runs a baseline. This is automatically repeated for about 40 countries in these tests. The batch mode is also of relevance in projects as all used settings are stored in a batch file. If then, for instance, some input data are changed based on feedback of clients, runs can be repeated in an automated fashion. Using the batch facility also excludes the problem that an analyst would involuntary instead of repeating the runs solely with the updated data also change the model setup by working with different GUI settings.

Summary

The MTI CGE team at the World Bank Group now provides an open-source version of its single country CGE MANAGE with a Graphical User Interface, shipped with a model documentation and all necessary files, including codes to derive a SAM for a country found in the GTAP Data Base, given a GTAP license. A matching default parameterization along with supplied recent GDP and demographic projections allows to develop long-run baselines in MANAGE for almost any country comprised in GTAP without further data. Such baselines also quantify emissions and Climate Change damages. Flexibility in the nesting of production functions and final demand, a rich set of tax instruments and a detailed government budget, including borrowing, render MANAGE an interesting model to analyze, for instance, scenarios related to Climate Change adaptation and mitigation or to tax reforms. A GAMS license is required for model runs, but not to explore existing results. A rich set of automatically generated reports support the analysis of results and reduce the need to familiarize in detail with model mnemonics.

An open-source version of a model provides transparency. It removes the risk of setting up and learning to use a model under restrictive Intellectual Property Rights for a specific project without a clear perspective of continued use. It allows third parties to scrutinize model equations, and not only the model documentation. It shares knowledge in a direct and accessible way. This is highly relevant for the World Bank Group, with its strong commitment to provide open data and support to good governance, to foster its aims to end extreme poverty and to promote shared prosperity in a sustainable way.

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