Integrating information from a national SAM to update and disaggregate the GTAP Data Base

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Abstract

We detail an approach to update country specific data in a (dis)aggregated GTAP Data Base, starting from a single country SAMs. Whereas data contributors to the GTAP Data Base deliver country specific IO-tables to the GTAP for inclusion in the build process of the GTAP Data Base, our approach starts from the given GTAP Data Base and updates macro totals, output, intermediate and final demand, imports and exports by product, tax rates etc. for the specific country, in order to keep as much information as possible from the available national SAM. The process is based on four steps. We first derive a GTAP Data set by aggregation, which comprises a single country and typically one Rest-Of-the-World aggregate, with products and sectors aggregated, such as to match as closely as possible the detail of the national SAM. If deemed useful and if data for the Rest-Of-the-World are available, we split the GTAP data to a finer product and sector detail. Second, we derive preliminary estimates at the country level, for the relevant aggregates in GTAP (demand of agents for imports and domestic production at market and agent prices, factor demands etc.). Third, we balance the resulting data, such as to match the values for the given single country SAM at its sector/product level, keeping consistency, for instance, regarding exhaustion conditions and market balancing. Fourth, the balanced single country data overwrite the given GTAP original data, and the whole framework is balanced again.

Keywords: Social Accounting Matrix, Macroeconomic Data, GTAP.

Background

There are many advantages in using the global GTAP Data Base for country-focused analyses. Yet, some CGE analysists rather prefer building their own model, and country-specific SAM.

It is argued, sometimes, that national I-O tables, used in the construction of the GTAP data set, are too old, or not sufficiently detailed. Indeed, and especially for developing countries, some data are outdated. For instance, the I-O tables for Ethiopia stem from 2002, and those for Kenya from 2001 (as transparently documented in the GTAP web site). About the detail, GTAP data could miss important export products, such as coffee, cocoa, or minerals.

A further argument is that a single country CGE model might comprise specific features not covered by the GTAP standard model, for which the global SAM does not provide supportive information. In this respect, a modular and extendable framework such as CGEBox (Britz and Van der Mensbrugghe 2018), which build on the GTAP family of CGE models and related data, may be especially useful. For instance, CGEBox comprises an extended version of the myGTAP model, to cover subsistence production at a sub-national level (Ferrari et al. 2018) for which also country specific data can be used. Furthermore, CGEBox is well documented, and give access to useful utilities, such those for result analysis and visualization (Britz et al. 2015).

The GTAP community encourages the submission of recent I-O tables and macroeconomic data, for possible inclusion in future releases of the global SAM. However, there are circumstances where this collaboration may not be sufficiently helpful. For example, an analyst may need updated data earlier then the targeted release date for the next GTAP data base, or with a different industrial classification.

Instead of developing a separate model and data set, one clever strategy could be deriving a “personalized variant” of the GTAP data base, having the desired detail, and embodying the updated country data. The process, which involves steps like aggregation, disaggregation, data correction and inclusion of recent macroeconomic data, is illustrated in this paper.

Methodology

In the following, by way of illustration, we give an overview of the process, which updates the country data for some African countries, using CGEBox. The methodology was devised and implemented in the context of a multi-year project of the EU’s Commission Joint Research Center, aimed at supporting African countries in the field of economic modeling. That involves assistance in the construction of recent national SAMs, with sub-national and household detail. So far, the newly developed data sets have not been integrated and combined with the GTAP one.

Preparation of a suitable GTAP Data Base for integrating of single country data

The first step consists in mapping products and sectors of an existing single-country SAM to the classification in GTAP. In cases where the single country SAM comprises more products and sectors than those in the GTAP data base, they could be aggregated, or kept distinct. This latter option may be especially sensible when it is important to consider the existence of special characteristics, like differences in tax rates. Keeping more product and sector detail of an existing national SAM requires a disaggregation of the GTAP data can be undertaken. In CGEBox, this is framed as a linear programming problem, which minimizes the linear loss (Britz, 2021). To this end, drivers are already available for different data bases. This refers first to FAO/FABIO (Bruckner et al. 2019) which gives high detail for agro-food intermediate use, production and final demand. Secondly, the EXIOBASE data (Stadler et al. 2018) can be used which gives more sector detail/product for industries and services with high environmental footprints. However, FAO/FABIO and EXIOBASE give no details on use taxes. Finally, bi-lateral trade and tariffs from TASTE (Pelikan et al. 2020) can be used.

The opposite case, where multiple sectors/products of the GTAP data base map to one sector/product in the country SAM, can be easily handled as a standard aggregation of the GTAP data base. This can also be done directly within CGEBox (Britz 2016).

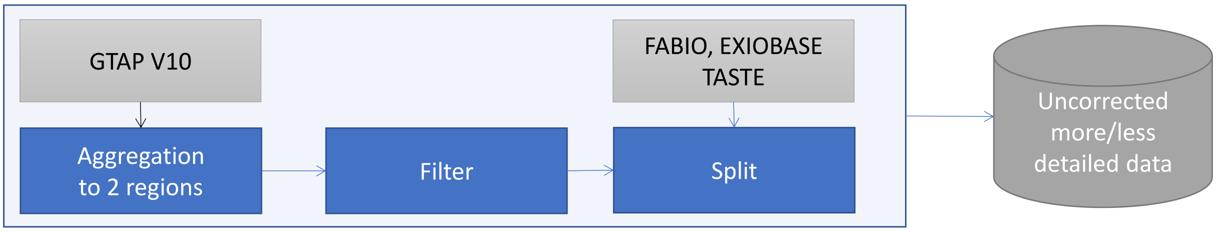

Figure 1: Overview on first step delivering a suitable data base for introducing updated single country information

Mapping of single country SAM data to the structure of the GTAP data base

The next step consists in transforming the national SAM into the structure of vectors and matrices as they are comprised in the GTAP data base. This requires a mapping of the codes of the products/sectors of the national SAM to the GTAP Data Base constructed in the step above. An example of mapping from the country SAM entries to the data structure in GTAP is shown below, as part of the GAMS script used for this step. This script comprises cross-set definitions, linking the national SAM columns/rows to the related elements in the GTAP data base. Wherever possible, these cross-sets comprise 1:1 maps of similarly defined products or activities.

```
set c_gtap(c,gtapc) "Mapping from JRC products to GTAP products" /
  ch_maiz.gro
  ch_whea.wht
  ch_rice.pdr
  ch_ogrn.gro
  ch_root.v_f
  ch_oils.osd
  ch_frui.v_f
  ch_vege.v_f
  ch_beef.(ctl,cmt)
  ch_dair.mil
  ch_poul.(oap,omt)
  ch_goat.(ctl,cmt)
  ch_oliv.(rmk,wol)
  ch_fish.fsh
  ch_bake.ofd
  ch_bevt.b_t
  ch_omfd.(ofd,vol,sgr,pcr)
  ch_watr.wtr

  c_maiz.gro
  c_whea.wht
  c_rice.pdr
  c_ogrn.gro
  c_root.v_f
  c_oils.osd
  c_frui.v_f
  c_vege.v_f
  c_cott.pfb
  c_sugr.c_b
  c_coff.ocr
  c_tea.ocr
  c_toba.ocr
  c_ocrp.ocr
  c_beef.ctl
```

Figure 2: Screen shot of example GAMS code mapping products from a single country SAM to GTAP

For the remaining n:m cases, one can use shares to construct estimates at the desired level of product and sector resolution.

The single country SAM is normally available as an Excel workbook, so it can be converted to a GDX binary file, for later employment in GAMS, through the appropriate conversion utility program.

In this specific exercise, national data does not comprise an agent-specific differentiation between domestic and import demand, nor an agent-specific tax rate. Therefore, import share and sales tax rates where estimated.

We show here an example how the information from the SAM is mapped to GTAP Data Base structure, referring to private consumption demand. As the single country SAMs comprise multiple households, by region and type (set *rh*) an aggregation is necessary, to arrive at total household demand (*vdpm*, values of domestic private demand at market prices, and *vipm*, values of imported private demand at market prices):

```
*
* --- aggregate over households demand to arrive at aggregate household (..p.. in vdpm and vipm)
*     demand at national level, product specific import share to distribute
*     to domestic and imported demand by households
*
  vdpm(gtapc,rnat) = sum((c_gtap(c,gtapc),rh), p_sam(c,rh) * (1 - p_importShare(c)) * (1-p_salTaxRate(c)) );
  vipm(gtapc,rnat) = sum((c_gtap(c,gtapc),rh), p_sam(c,rh) *      p_importShare(c)  * (1-p_salTaxRate(c)) );
```

In case of a 1:1 mapping from single country SAM to GTAP, this already generates estimates for the GTAP data in the correct format. Another simple case occurs when the country SAM considers less product detail compared to GTAP. Then, shares from GTAP for single products in the related aggregates from the national SAM can be employed for disaggregation:

```
*
* --- distribute according to GTAP shares in case of duplicate mappings
*     (multiple GTAP products linked to one product in the SAM)
*
  vdpm(gtapCdpl,rnat) $ vdpm(gtapCdpl,rnat)
     = vdpm(gtapCdpl,rnat) * vdpmGTAP(gtapCdpl,rnat)/sum(gtapcc(gtapcDpl,gtapc),vdpmGTAP(gtapc,rnat));

  vipm(gtapCdpl,rnat) $ vipm(gtapCdpl,rnat)
     = vipm(gtapCdpl,rnat) * vipmGTAP(gtapCdpl,rnat)/sum(gtapcc(gtapcDpl,gtapc),vipmGTAP(gtapc,rnat));
```

The set *gtapCDpl* comprises the sub-set of GTAP products where multiple mappings to products in the national SAM occur. The cross-set *gtatpcc* depicts groups of GTAP products mapped to the same product in the country SAM.

To ensure that total domestic and import household demand from the JRC SAM is maintained, we defined these totals from the single products in the SAM, again adding over the households:

```
*
* --- Store total for scaling
*
  p_comp(rnat,"vpm1","imp","JRC") = sum( (c,rh), p_sam(c,rh) * (1-p_salTaxRate(c)) *      p_importShare(c) );
  p_comp(rnat,"vpm1","dom","JRC") = sum( (c,rh), p_sam(c,rh) * (1-p_salTaxRate(c)) * (1 - p_importShare(c)));
```

The same sum of defined for the individual GTAP products and given GTAP data:

```
  p_comp(rnat,"vpm2","imp","JRC") = sum( gtapC, vipm(gtapC,rnat));
  p_comp(rnat,"vpm2","dom","JRC") = sum( gtapC, vdpm(gtapC,rnat));
```

Followed by scaling of each individual item, based on the two totals:

```
*
* --- scale to recover original total (domestic + imported)
*
  vipm(gtapC,rnat) = vipm(gtapC,rnat) *  p_comp(rnat,"vpm1","imp","JRC")/p_comp(rnat,"vpm2","imp","JRC") ;
  vdpm(gtapC,rnat) = vdpm(gtapC,rnat) *  p_comp(rnat,"vpm1","dom","JRC")/p_comp(rnat,"vpm2","dom","JRC") ;
```

A similar method is used for government, investment, and intermediate demand. For the latter, both goods and activities are separately considered.

Data consolidation through non-linear programming

After the initial estimates for the different elements of demand, imports and exports, factor demands and tax revenues are derived as detailed for the example of household demand above, we apply a balancing framework to derive internally consistent estimates which exhaust the given data from the SAM. This is based on a non-linear program (NLP)which minimize the squared difference between data estimates in GTAP format, initially derived from the country SAM, and a new set, where some balancing conditions (e.g., market clearance) are imposed.

This was necessary in our exercise because, for example, a distinction between imported and domestic origin, as in the GTAP data base, is not made in the national SAMs. This would result in biases for total imports and domestic sales, inconsistent with original data, which are removed by the NLP adjustment. Also, the single country data showed less detail regarding tax rates. We then used split factors from GTAP to get the required detail.

First, the sum of all imports,[1] as reported in the single country SAM is recovered based on the following constraint as part of the NLP framework, where symbols with v_ depict variables to balance, here the individual imports for each product in GTAP definition:

```
 e_imports(rnat) ..

          sum(cc_gtap(c,gtapc) $ p_imports(gtapc,"jrc",rnat), v_imports(gtapc,rNat))
                 =E= sum(ccc(c,c1),p_sam("row",c1) + p_sam("imptax",c1));
```

For exports, we keep exports by product with the following constraint:

```
*
* --- keep total JRC exports by product
*
  e_exports(rnat,c) ..

     sum(cc_gtap(c,gtapc) $ p_exports(gtapc,"jrc",rNat), v_exports(gtapc,rNat)) =E= sum(ccc(c,c1),p_sam(c1,"row"));
```

And a similar one for imports by product:

```
*
* --- keep total JRC imports by product group (with slacks, reason why this is needed unclear)
*
  e_imports(rnat,c)  ..

        sum(cc_gtap(c,gtapc) $ p_imports(gtapc,"jrc",rnat), v_imports(gtapc,rNat) + v_imports(gtapc,rNat)*v_importSlack(gtapc,rnat))
             =E= sum(ccc(c,c1),p_sam("row",c1));
```

A constraint is added with enforces exhaustion of the domestic output for each product by balanced exports and domestic use; where, all involved elements are endogenous variables:

```
*
* -- make sure that domestic demand plus exports are exhausted by total costs + production taxes of delivering activity
*    (diagonal make structure)
*
  e_exhaustDom(gtapc,rnat) ..

          v_vdpm(gtapc,rnat) $ vdpm(gtapc,rnat)
        + v_vdgm(gtapc,rnat) $ vdgm(gtapc,rnat)
        + sum(gtapAI $ vdfm(gtapc,gtapAI,rNat), v_vdfm(gtapc,gtapAI,rNat))
        + v_exports(gtapc,rNat) $ p_exports(gtapc,"jrc",rNat)

         =E=

        v_indTax(gtapc,rNat) $ p_indTax(gtapc,"JRC",rnat)
         + sum(gtapF $ vfm(gtapF,gtapc,rnat), v_vfm(gtapF,gtapc,rnat)*(1/(1-p_facTax(gtapF,"rate",rnat))))
         + sum(gtapc1 ,   v_vdfm(gtapc1,gtapc,rnat)*(1/(1-p_salTax(gtapC1,"rate",rnat)))  $ vdfm(gtapc1,gtapc,rnat)
                       + v_vifm(gtapc1,gtapc,rnat)*(1/(1-p_salTax(gtapC1,"rate",rnat)))  $ vifm(gtapc1,gtapc,rnat) );
```

Another constrains ensures the exhaustion of production taxes as reported in the SAM:

```
*
* --- exhaustion of all indirect taxes
*
  e_exhaustIndTax(rnat) ..

    sum(gtapc $ p_indTax(gtapc,"JRC",rnat),v_indTax(gtapc,rnat)) =E= sum(a, p_sam("indtax",a));
```

Imports by GTAP product, from the intermediate and final demands, are defined base on the following constraint:

[1] Enforcing this for each product individually provokes infeasibilities in one market. Therefore, deviations from imports receive a high weight in the objective function instead.

```
*
* --- exhaustion of imports by import demand of Armington agents
*
 e_exhaustImp(gtapc,rnat) ..

       v_vipm(gtapc,rnat) $ vipm(gtapc,rnat)
     + v_vigm(gtapc,rnat) $ vigm(gtapc,rnat)
     + sum(gtapAI $ vifm(gtapc,gtapAI,rNat), v_vifm(gtapc,gtapAI,rNat)) =E= v_imports(gtapc,rNat) $ p_imports(gtapc,"jrc",rNat);
```

Total private, government and saving demand net of sales taxes as reported in the national SAM (RHS) are recovered by the balanced estimates (LHS) in the following constraints:

```
*
* --- exhaustion of total private demand by group of JRC products
*
 e_keepTotalP(c,rnat) ..

   sum(cc_gtap(c,gtapc),     v_vipm(gtapc,rnat) $ vipm(gtapc,rnat)
                           + v_vdpm(gtapc,rnat) $ vdpm(gtapc,rnat))

    =E= sum(ccc(c,c1),sum(rh, p_sam(c1,rh))*(1-p_salTaxRate(c1)));
*
* --- exhaustion of total government demand by group of JRC products
*
 e_keepTotalG(c,rnat) ..

      sum(cc_gtap(c,gtapc),  v_vigm(gtapc,rnat) $ vigm(gtapc,rnat)
                           + v_vdgm(gtapc,rnat) $ vdgm(gtapc,rnat))

      =E= sum(ccc(c,c1),p_sam(c1,"govert")*(1-p_salTaxRate(c1)));
*
* --- exhaustion of total investment demand by group of JRC product
*
 e_keepTotalS(c,rnat) ..

          sum(cc_gtap(c,gtapc), v_vifm(gtapc,"cgds",rnat) $ vifm(gtapc,"cgds",rnat)
                              + v_vdfm(gtapc,"cgds",rnat) $ vdfm(gtapc,"cgds",rnat))

       =E= sum(ccc(c,c1),p_sam(c1,"i-s")*(1-p_salTaxRate(c1)));
```

Similarly, for total intermediate demand:

```
*
* --- exhaustion of total intermediate demand by group of JRC products
*
 e_keepTotalI(c,rnat) ..

      sum((cc_gtap(c,gtapc),gtapA),    v_vifm(gtapc,gtapA,rnat) $ vifm(gtapc,gtapA,rnat)
                                     + v_vdfm(gtapc,gtapA,rnat) $ vdfm(gtapc,gtapA,rnat))

        =E= sum(ccc(c,c1),sum(a, p_sam(c1,a))*(1-p_salTaxRate(c1)));
```

Finally, for factor demands:

```
*
* --- exhaustion of total factor demand
*
 e_keepTotalF(f,rnat) ..

         sum((ff_gtap(f,gtapf),gtapA), v_vfm(gtapF,gtapA,rnat) $ vfm(gtapF,gtapA,rnat))

        =E= sum((fff(f,f1),a), p_sam(f1,a)* ( 1 - p_facTax(f1,"rate",rnat)));
```

By minimizing a quadratic loss, the NLP program delivers balanced estimates for the variables (*v_*) shown above, which are initialized before the NLP problem is solved:

```
*
* --- Assign from parameters to variables as start point
*
  v_indTax(gtapc,rnat)         =     p_indTax(gtapc,"jrc",rNat);
  v_imports(gtapc,rnat)        =     p_imports(gtapc,"jrc",rNat)  + p_imptx(gtapc,"jrc",rNat);

  v_exports(gtapc,rnat)        =     p_exports(gtapc,"jrc",rNat);

  v_vdpm(gtapc,rnat)           =     vdpm(gtapc,rnat);
  v_vipm(gtapc,rnat)           =     vipm(gtapc,rnat);

  v_vdgm(gtapc,rnat)           =     vdgm(gtapc,rnat);
  v_vigm(gtapc,rnat)           =     vigm(gtapc,rnat);

  v_vdfm(gtapc,gtapAi,rnat)    =     vdfm(gtapc,gtapAi,rnat);
  v_vifm(gtapc,gtapAi,rnat)    =     vifm(gtapc,gtapAi,rnat);

  v_vfm(gtapF,gtapC,rnat)      =     vfm(gtapF,gtapC,rnat);
```

The balanced estimates are assigned back to the parameters, after a solution is found:

```
  solve bal using NLP minimizing v_quaLoss;
*
* --- Assign final solution back to parameters
*
  p_imports(gtapc,"jrc",rNat) = v_imports(gtapc,rnat) - p_imptx(gtapc,"jrc",rNat);
  p_exports(gtapc,"jrc",rNat) = v_exports(gtapc,rnat);

  vdpm(gtapc,rnat)            = v_vdpm(gtapc,rnat);
  vipm(gtapc,rnat)            = v_vipm(gtapc,rnat);

  vdgm(gtapc,rnat)            = v_vdgm(gtapc,rnat);
  vigm(gtapc,rnat)            = v_vigm(gtapc,rnat);

  vdfm(gtapc,gtapAi,rnat)     = v_vdfm(gtapc,gtapAi,rnat);
  vifm(gtapc,gtapAi,rnat)     = v_vifm(gtapc,gtapAi,rnat);

  vfm(gtapF,gtapC,rnat)       = v_vfm(gtapF,gtapC,rnat);
```

Updating the GTAP Data

The result of the process described above are data structure in the definitions and format of the GTAP Data Base, derived from the national SAM and consistent to it at an product and sector level chosen by the analyst, but not yet integrated with the GTAP Data Base. To remove inconsistencies between the rest-of-the-world data from GTAP Data Base and the set of new national data, a data balancing method, originally developed by Rutherford (1998), is employed (see also Britz and Van der Mensbrugghe, 2016).

The single country data derived from the national SAM overwrite the corresponding one in the GTAP set. Trade flows for all regions are then fixed, and data for all regions balanced at given import and export flows. Changes for regions will then reflect changes in trade with the inserted country, which will also imply some variations in macro totals if these changes have sizeable impact on their balance of trade.

Finally, an optional feature available in CGEBox can be employed, to update some important macro variables (such as GDP, labor and capital stocks, population) to recent statistical information. To this end, the G-RDEM model (Britz and Roson, 2019, Roson and Britz, 2021) can be utilized. G-RDEM considers capital accumulation mechanism and endogenizes total factor productivity. It also considers other important structural change mechanisms, which are especially relevant in cases of sustained economic development: (1) factor productivities for three broad sector depend on overall factor productivity and the speed of economic growth, (2) saving rates depend on income levels and demographics, (3) costs shares are updated, based on income levels and (4) balance of trade imbalances are linked to debt accumulation. Furthermore, (5) an empirically estimated MAIDADS demand system (Britz, 2021) brings in more flexibility in terms of income demand elasticity, compared to the CDE demand system in the GTAP standard model (cf. Ho et al., 2020).

Discussion

Embodying a single country SAMs into the GTAP Data Base is a highly challenging task because the various SAMs differ in their structure. For instance, the differentiation in demand between domestic and imported origin may not be specified separately for each agent, as it is in the GTAP data base.

A further difficulty is related to non-diagonal make matrices, which could be found in some national SAMs, where one (often broadly defined activity) is associated with a long list of products. To map this information to the GTAP data base, intermediate data structures had to be built, using proportionality assumptions. Informed choices about how to best overcome structural differences between the data sources requires in-depth knowledge of both the GTAP structure (and its build process) and of the the single country SAM. One also needs to consider that GTAP data are not released for all years, so there is no guarantee that national SAM refer to the same year as the latest GTAP release.

Summary and conclusions

While the preferred way of bringing in more recent country data to the GTAP community is to become a data provider, there might be cases where a project requires updating data for a specific country in the existing global GTAP data set. We discussed here an approach, which first constructs a GTAP data base with the desired product/sector, regional and primary factor detail, next derives data in the GTAP format and definitions from a given SAM which replace the original country data in the GTAP Data Base, and then re-balances data in the other model regions, to ensure global consistency. Despite its technical complexity, the procedure presented in this work allows benefitting from the availability of recent national data, while retaining the coverage, flexibility, and consistency of the base GTAP SAM. This would allow a modeler to conduct a wider range of simulation exercises.

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