Using *Howler* to check GTAP databases for anomalies

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Introduction

Preparation of the GTAP database relies on the inputs of many contributors. The GTAP team at Purdue uses programs to assemble the input-output databases of over 150 regions, reconciling national data and Comtrade data on global trade. The reach of the database among users over three decades is testimony to the success of GTAP.[1] Yet the complexity of assembling and refining the GTAP database means that potential anomalies may arise. The objective of this paper is to outline a program that presents a systematic overview of potential errors in the master database. The program can also be applied to different database aggregations.

The dimensions of GTAP's master database might imply that tests concerning CGE database veracity are daunting. Nevertheless, it is possible to examine key database features by region. Several tests presented here are based on comparing GTAP databases from different years. Others concern a single database. One compares macroeconomic accounts calculated within the GTAP database with those prepared by UN. Another check is to tag individual cells within the input-output structure of the model that may be implausibly large.

An outline of the programs used to check a GTAP database follows.

Reducing a GTAP database to a few matrices

A first step in examining GTAP is to reconfigure the full dimensions of the core database for a given year to a small number of matrices. Mark Horridge of the Centre of Policy Studies has prepared such a program, *GTP2NORM.tab*, found in the suite of database splitting programs in *Splitcom* (downloadable from https://www.copsmodels.com/splitcom.htm). In order to compare databases, we reconfigure GTAP data from different years to a common form. The archive item https://www.copsmodels.com/archivep.htm TPMH0203 provides a program that enable us to convert version 7 GTAP to version 6, the latter being compatible with *GTP2NORM.*

The NATIONAL matrix consists of five dimensions as follow:
Cost = commodities + 8 types of labour + capital + natural resource rents + production taxes
Src = domestic, imported
User = industries + households +investment + government
REG = regions
TYP = basic flows + indirect taxes

The NATIONAL matrix is assembled from 20 matrices within the core GTAP database. It includes all intermediate and primary inputs to all industry users plus all final uses of commodities.

[1] See https://www.gtap.agecon.purdue.edu/about/history.aspx#DBhist.

The only edit made to GTP2norm.tab is to add the expenditure side components of GDP to the outfile (appendix 1). The expenditure-side GDP calculations use two additional matrices computed in GTP2NORM, namely WEIGHTS and SUMMARY.

WEIGHTS includes three dimensions, SEC, MOREWGT and REG.

SEC = commodities = industries

MOREWGT = “Production” + “IntUse” + “Absorption” + “Exports” + “Imports”

WEIGHTS combines the three domestic components of expenditure-side GDP. For comparative purposes, private consumption, investment and public consumption are displayed, using calculations from the SUMMARY matrix.

The MAKE matrix, showing the commodity output value of each industry, is among the matrices written to outfiles by *GTP2NORM*.

Identifying large differences between databases from different years

Howler enables the user to compare databases for three different years. In the case of the full GTAP dataset, additional regions and additional sectors have been prepared in more recent versions. Within TABLO, different sectoral and regional sets are dealt with by creating new sets, defined as the intersection of sets from different databases:

Consider databases for 2017, 2014 and 2004. In the NATIONAL matrix for 2017, define commodities COM17 as

```
Set Com17 = Cost - Factors - "Ptax";
```

Howler coding includes provision for different commodities in earlier databases. Let oCost be the first set in the NATIONAL database for 2014 and 2004:

```
Set Com14 = oCost - Factors - "Ptax";
```

The regions of the 2017 database are REG, while those read from 2014 and 2004 are oREG. A new set Regok is the intersect of REG and oREG. The industry sets contain the same elements as the commodity sets:

```
Set IND = Com17;
Set oIND = Com14;
Set INDok = Ind intersect oIND;
Set Regok = Reg intersect oReg;
```

Structural change over time

One comparison undertaken in *Howler* is of the MAKE matrix for a given industry by region between two different years. As economies mature, agriculture’s share of GDP may shrink over time. Developing economies may experience growth in manufacturing output as a share of GDP. High income countries may see shrinkage in manufactures as competitiveness is lost with rising relative costs. The following block of code checks for subset of sectors by regions with marked differences between two databases.

```
Coefficient (all,i,IndOK)(all,r,RegOK) Expand14to17(i,r);
 (all,i,IndOK)(all,r,RegOK) Shrink14to17(i,r);!the numbers below GDPPI: 102.4
```

```
2014, 107.4 2017!
Formula (all,i,IND)(all,r,REG) MAKE17_C(i,r) =sum{c,Com17,MAKE17(c,i,r)};
(all,i,oIND)(all,r,oREG) MAKE14_C(i,r) =sum{c,Com14,MAKE14(c,i,r)};
(all,i,IndOK)(all,r,RegOK) Expand14to17(i,r) =
    if{102.5/107.4* MAKE17_C(i,r)/MAKE14_C(i,r)>1.52,if{MAKE17_C(i,r)>50, 1}};
(all,i,IndOK)(all,r,RegOK) Shrink14to17(i,r) =
    if{102.5/107.4* MAKE17_C(i,r)/MAKE14_C(i,r)<0.61,if{MAKE14_C(i,r)>50, 1}};
```

Two groups of coefficients are defined, Expand14to17 and Shrink14to17. The US GDP deflator for each year is used to account for a rise in the general price level over time. Note that sectors in which the value of output is less than $50 million are excluded. Expand14to17 is a binary matrix, in which expansion larger than 52% in the three year period is designated as 1.0, else zero. Shrink14to17 is a similar matrix covering sectors in which output in 2017 falls to less than 61% of 2014 output.

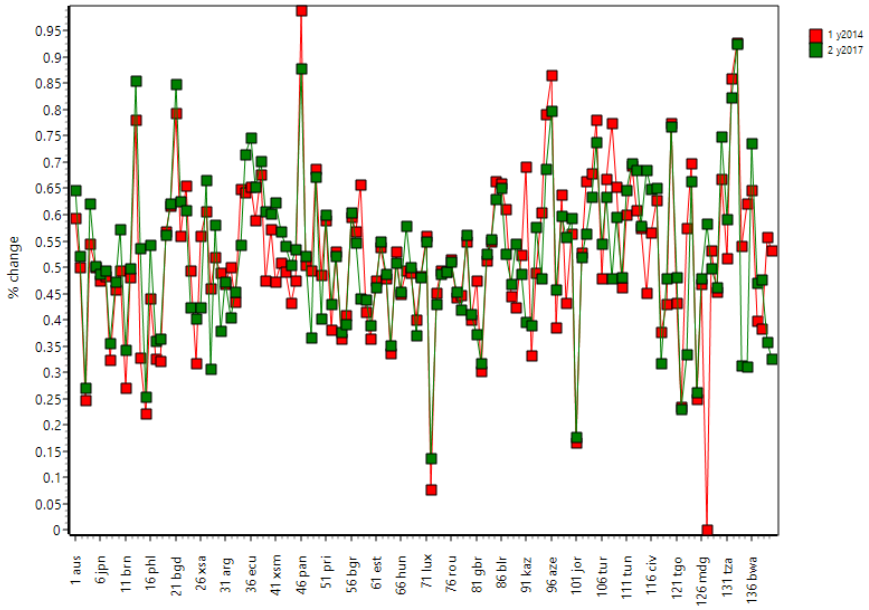
Given that such changes are expected, any program to check comparative databases should involve sifting of outliers that may be anomalies from changes that may reflect actual economic change. In the case of agriculture, output changes may occur between years due to seasonal conditions, or price-induced changes in outputs.

There is shrinkage in China's oil and gas output between 2014 and 2017 in GTAP. This may be relevant in some scenarios, and therefore worthy of project-specific investigation.

Technologies

Some studies may requires a comparison of technologies over time. Differences in technologies or preferences will result in input-share or expenditure-share changes over time (Dixon and Rimmer, 2023). For example, we would expect to observe an increase in information technology inputs across industries over the past couple of decades. However, it is also possible that an apparent technological change reflects a change in convention at a national statistical agency. Such a change, arising from a data artefact, confounds economic interpretation.

Figure 1: Ratio of construction share of investment, GTAP 2014 v. 2017



At this stage, *Howler* technology checks are limited to the construction sector's share of investment. Figure 1 shows

$$R_{ct} = (Cns_{ct}/INV_{ct})/\Sigma_t\,(Cns_{ct}/INV_{ct}) \qquad t=2014,\ 2017 \quad (1)$$

where R is the ratio in year t and region c of the construction input CNS share of investment INV divided by the sum of the construction share over the year t. If the ratios in the two years are identical, the ratio equals 0.5 for each year. The only country in which the ratios deviate alarmingly from 0.5 is Malawi, in which there were virtually no construction inputs into investment in the 2014 database.

Unusual conventions

The tendency of some nations to release national databases that reflect targets rather than observations may create a concern. Moreover, in the GTAP database, Dwellings activity in former Soviet economies is an abnormally small share of economic activity. This is possibly defensible but may warrant further examination in some scenarios. An example of a strange result arose in a TERM/EuroTERM[2] course held in Vienna in September 2022. In an aggregation which included Russia as a region, using a short-run setting, results for Russia were markedly different from elsewhere. This arose because in a short-run scenario, capital (which is specific to each industry in TERM/EuroTERM) is fixed. Dwellings costs consist substantially of capital rentals.

A database checking program is a way of identifying anomalies and outliers in any aggregation of the GTAP database. *Howler* enables us to compare components of expenditure-side GDP from a new GTAP database with other sources, notably UN. The

[2] The EuroTERM database relies on GTAP for national data.

program facilitates early identification of database outliers that may otherwise lead to problems deeper into a research project.

Macroeconomic accounts

An earlier version of the GTAP 2017 database included a balance of trade deficit for Canada that was substantially larger than that found in official sources such as the OECD (Dixon and Rimmer, 2024). When it came to projecting a dynamic version of GTAP into the future, this resulted in implausible macro accounts for Canada. This is because a large net trade deficit builds up net foreign liabilities in a dynamic model. Consequently, disposable income as a share of GDP is lower than otherwise, resulting in aggregate consumption growing much more slowly than real GDP.

Howler compares the macroeconomic accounts in GTAP with UN data downloaded from https://unstats.un.org/unsd/snaama/Basic. These have been processed using CSV2HAR (see https://www.copsmodels.com/gpmark.htm) and a TABLO program which creates an infile to *Howler*. Figure 2 shows the ratio of GDP denoted by GDPR in country c and data source s:

$$GDPR_{cs} = GDP_{cs}/\Sigma_s GDP_{cs} \qquad s=\text{GTAP 2017, UN 2017} \qquad (2)$$

In most regions shown in figure 2, GDP from the two sources is close to 0.5 (i.e, the two sources are equal at 0.5).

The biggest outlier concerns Haiti, an addition to GTAP. Inspection of the GTAP database base showed that both GDP and population in the country are understated many-fold. Discrepancies of this magnitude need to be sorted prior to modelling for any study in which Haiti is of interest. The next biggest discrepancy is in *xcb* (Rest of Caribbean). Beyond these two outliers, the two databases align remarkably well.

Figure 2: 2017 GDP ratios, GTAP v. UN

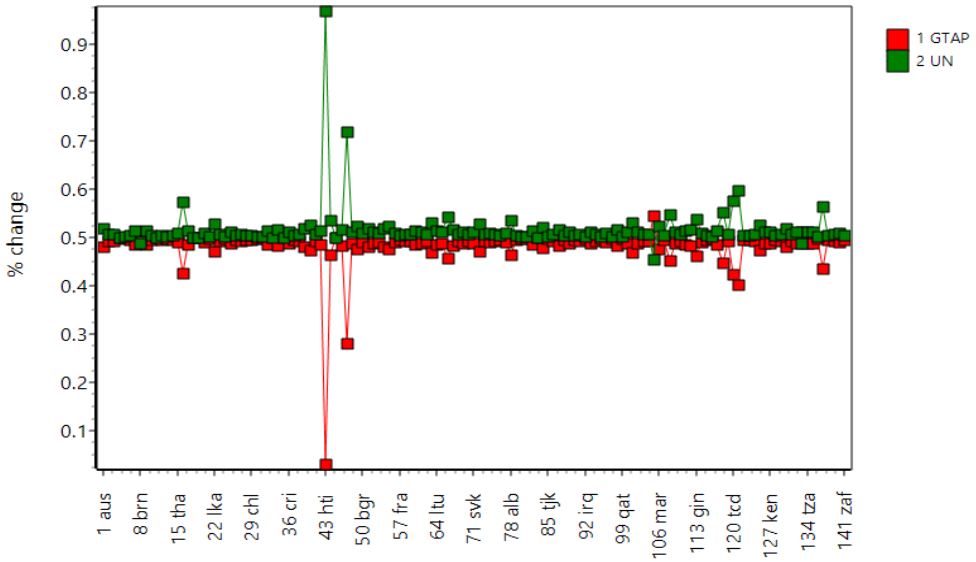


Figure 3: 2017 aggregate household consumption ratios, GTAP v. UN

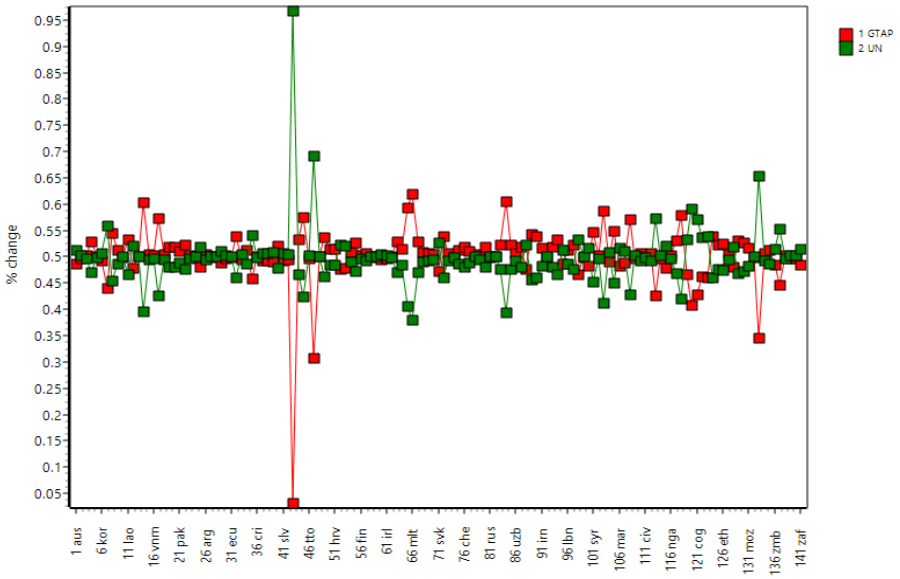


Figure 3 shows the ratio of aggregate household consumption denoted by ConR in country c and data source s:

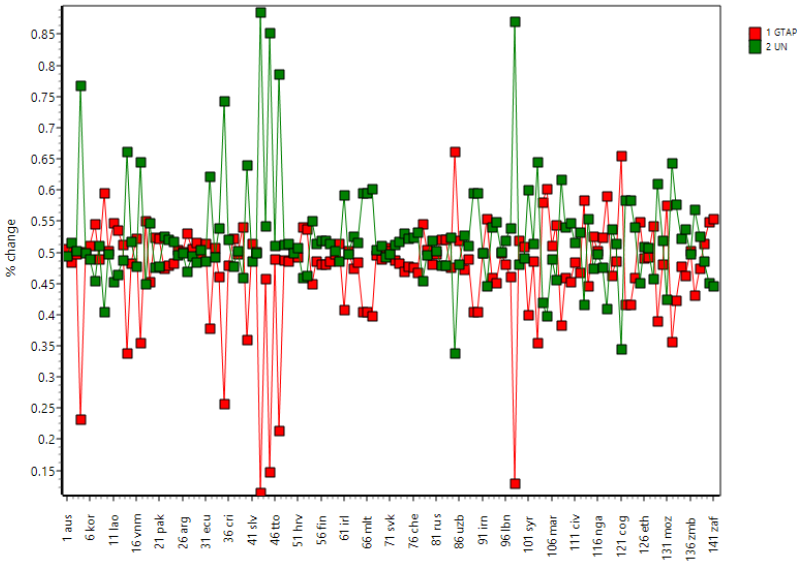
$$ConR_{cs} = Con_{cs}/\Sigma_s Con_{cs} \qquad s=GTAP\ 2017,\ UN\ 2017 \qquad (3)$$

Haiti as expected is an outlier. In a small number of other countries, the UN estimate is up to twice as high as the GTAP estimate. In particular studies, these moderate discrepancies may warrant further investigation.

Figure 4 shows the ratio of export values denoted by ExpR in country c and data source s:

$$ExpR_{cs} = Exp_{cs}/\Sigma_s Exp_{cs} \qquad s=GTAP\ 2017,\ UN\ 2017 \qquad (4)$$

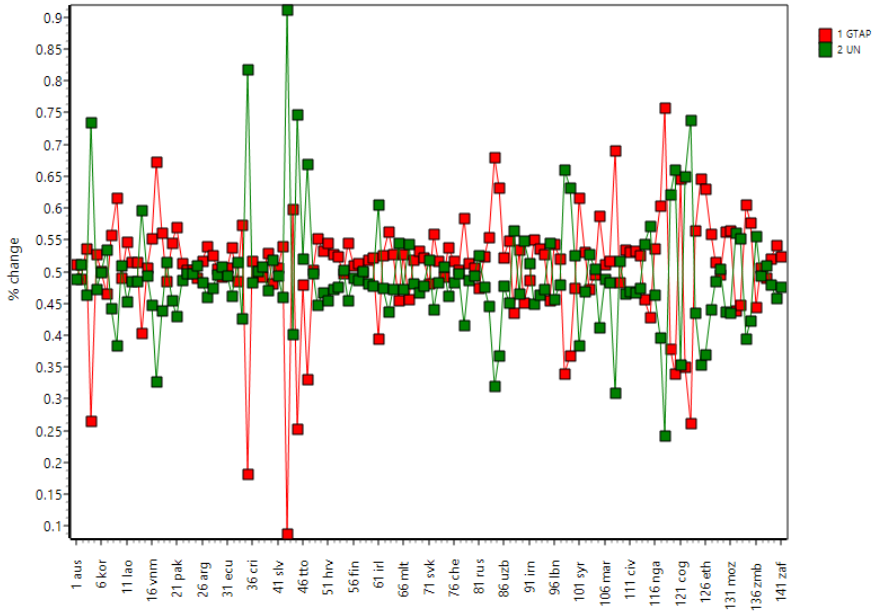
Figure 4: 2017 export value ratios, GTAP v. UN



The import ratio ImpR (figure 5) in country c and data source s is:

$$ImpR_{cs} = Imp_{cs}/\Sigma_s Imp_{cs} \qquad s=GTAP\ 2017,\ UN\ 2017 \quad (5)$$

Figure 5: 2017 import value ratios, GTAP v. UN



An examination of aggregate exports and imports reveals a difference in convention between GTAP and UN in the case of key entrepot economies, Singapore and Hong Kong. In GTAP, exports and imports are netted out, resulting in smaller aggregates relative to UN with little change to net trade. In a case in which GTAP and UN are inconsistent at the macro level, it

may imply an inconsistency between UN Comtrade data and UN macroeconomic data, rather than a problem with GTAP data processing. When processing global data, reconciliation from different sources is a demanding task.

An economy in which both exports and imports are large relative to GDP is Vietnam. GTAP and UN agree on this. A check of online sources indicates that Vietnam has attracted substantial foreign investment over the past decade or so. Comparing GTAP 2017 to GTAP 2014 data, there has been rapid growth in some manufacturing sectors. We may infer that Vietnam's manufactures are highly import-intensive. The industry *ele* (computer, electronic and optical products) has imports of $65 billion in total production costs of $119 billion in 2017. Of these imports, almost $59 billion are own-inputs, accounting for 20% of total Vietnamese imports in the GTAP database.

Sales that are a large share of GDP

Howler identifies cells in the NATIONAL database in which commodity sales to users exceed either 20% or 40% of GDP. In some instances, such as food sales to households in low income countries, a large share of GDP may be defensible. For example, v_f (vegetables, fruits, nuts) sales to households exceed 20% of GDP in six GTAP regions in the 2017 database. Similarly, in 17 regions, cns (construction) sales to investment exceed 20% of GDP. Once the threshold rises to 40% of GDP, we may have more substantial concerns. Panama is the only country in which *cns* sales to investment exceed 40% of GDP. However, in GTAP and UN data, investment accounts for 46% and 42% of GDP respectively. On this basis, the construction sale share of Panama's GDP is defensible. The *v_f* sale to households in Malawi exceeds 40% of GDP, again plausible.

New regions in GTAP database

The GTAP consortium prepares data for an ever-growing number of individual countries. Anomalies have arisen in the case of big countries such as Canada, at least in an earlier version of the GTAP 2017 database. Consider potential entrants to the GTAP list of countries. It is probable that in smaller countries, without official input-output tables at all, there may be even greater scope for anomalies. In the Australian context, two neighbouring countries of particular interest not yet in GTAP are Papua New Guinea and Fiji. In the case of the former, the National Statistical Office has not prepared an input-output table since independence in 1974. Researchers either in or associated with the Centre of Policy Studies have prepared several PNG CGE databases, most recently based on IFPRI data. Any Fijian CGE database is likely to start with the annual tables provided by the Asian Development Bank. The frequency of these tables may expose issues in anomalies from one year to the next.

CGE databases improve with use. For example, it appears unlikely that any practitioner has used GTAP to examine scenarios in Haiti. Feedback to the GTAP database team from users result in ongoing improvements.

Responding to database problems

If *Howler* detects a problem that is relevant to a particular project, tools are available to amend the GTAP database. Amid the many programs written by Mark Horridge to assist GTAP developers and users is *GTAPAdjust*. This is downloadable from

https://www.copsmodels.com/archivep.htm item TPMH0104. The briefest summary of this program is that after amending a GTAP database, the program enables the user to restore database balance. This may be used in a sequence of Horridge programs, including those cited above.

Conclusion

The database checking program *Howler* may compare databases from different years, or check how an individual database aligns with macro accounts from elsewhere. It also checks for excessively large sales within individual database cells. In addition, *Howler* checks for value outliers relative to the size of a given national economy. *Howler* has been designed to help users of the GTAP database find potential trouble spots within the data. The Canadian import example cited above is an example in which the forecast path was derailed, due to macroeconomic level in an earlier GTAP version not aligning with other data sources. Early detection of anomalies will assist in the progress of some projects.

The user may aggregate both GTAP and UN-based macro accounts to regions of interest prior to using *Howler*. In some applications, the user may wish to extend *Howler*. For example, the user may wish to check GTAP agricultural outputs against FAO data. This would require data on prices in order to convert FAO data to values. The objective in creating *Howler* is to assist the user in checking the suitability of GTAP data for a particular project.

References

Dixon, P. and Rimmer, M. (2024), Creating a GTAP baseline for 2014 to 2050 with special reference to Canada. Centre of Policy Studies Working Paper G-345.

https://www.copsmodels.com/splitcom.htm

https://www.copsmodels.com/archivep.htm items TPMH0203 and TPMH0104.

An archive containing Howler and UN macro accounts is downloadable as a GTAP resource.