MyGTAP Model

A Model for Employing Data from the MyGTAP Data Application
Multiple Households
Split Factors
Remittances
Foreign Aid
Transfers

Terrie Walmsley and Peter Minor
Important Acknowledgments and Conditions (must read)

MyGTAP was originally funded by the Bank of the Netherlands Partnership program, a joint program with the World Bank. William Martin, Team Leader and Director. This paper is based on a report submitted as part of the BNPP. Further improvements and features have been added.

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For the most up to date MyGTAP documentation, model, or programing code, visit: MyGTAP.ORG.
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Introduction

The purpose of this paper is to document an extension to the GTAP model (Hertel, 1997) to incorporate an alternative specification of the regional household as well as the addition of various inter-regional transfers\(^1\). This new model was developed with the following aims: a) to give the user more flexibility in the treatment of government savings and spending; b) to include inter-regional transfers, such as remittances and foreign capital incomes; and c) to allow the user to model the impact of a policy on different households and factors within an economy/ies of interest for which they have additional data.

The following is a brief summary of the changes made in the development of this model:

1. The regional household has been removed and replaced with a separate government and private household:
   a. Government now collects income from taxes and foreign aid and uses this money to consume (Government expenditure). The difference between government income and consumption is the government deficit or saving.
   b. Private households receive income from factors, including foreign remittances and capital and use this money to consume and save.

2. Inter-regional transfers such as labor remittances, foreign income on capital and foreign aid have been included into the model.

3. The model allows for multiple private households to be specified in one region or country\(^2\). Hence each private household holds endowments and receives income from those endowments.

4. Private household expenditure can now be allocated across commodities using either the Constant difference elasticity (CDE) or Linear expenditure system (LES) specifications. The method used can be altered by the user and can differ by country/region.

Each of these changes is discussed in turn below, followed by a section on areas for future development.

Note that this document is meant to be used in conjunction with a GTAP database splitting program (MyGTAP Data Program) which creates the database for use with this model\(^3\). We strongly suggest that this document be reviewed in conjunction with the MyGTAP Data program documentation before initial use.

---

\(^1\) The model is written in GEMPACK, see Harrison and Pearson (2007)

\(^2\) Future extensions will allow multiple households in more than one region or country

\(^3\) MyGTAP is documented in Minor and Walmsley (2012).
The Removal of the Regional Household

In the GTAP model, a single regional household collects all income from factors and taxes and allocates this income to private consumption, government and (regional) savings using a Cobb Douglas function (see figure 1). Our first task was to remove this regional household and replace it with a separate government and private household (see figure 2).

The government is assumed to gain income from taxes (TTAX), foreign aid in (AIDI), less foreign aid out (AIDO) and other transfers (TRNG) from government to private households (equation 1)\(^4\). It is assumed that foreign aid is received directly by each country/region’s government, not directly by private households.

\[
\text{GOVINC}(r) = \text{AIDI}(r) - \text{AIDO}(r) + \text{TTAX}(r) - \sum(h, \text{HHLD}, \text{TRNG}(h,r))
\]

(1)

Where \( r \in \text{REG} \)
\( h \in \text{HHLD} \) (private households, assume this is a single private household)

This income (\(\text{gincome}\) in percentage changes) is then used by the government to fund government expenditure (\(\text{yg}\), equation 2) and government savings (\(\text{psave} + \text{qgsave}\) or \(\text{govdef}\), equation 3). The difference between government income and consumption is the government deficit or saving (\(\text{govdef}\), equation 4). The user can assume that the share of government expenditure in income remains constant or they can specify alternative assumptions, such as fixing the government deficit\(^5\).

\[
\text{yg}(r) - \text{gincome}(r) = \text{dpgov}(r) - \text{dpgav}(r)
\]

(2)

\[
\text{psave}(r) + \text{qgsave}(r) - \text{gincome}(r) = \text{dpgsave}(r) - \text{dpgav}(r)
\]

(3)

\[
\text{govdef}(r) = \text{gincome}(r) - \text{yg}(r)
\]

(4)

---

\(^4\) Note this is a levels formula for manipulating the data. Upper case denotes levels, while lower case denotes percentage changes. A complete list of new variables and coefficients used in this paper are provided in Appendix 1. The tab files are also available on request.

\(^5\) By adding the following statement to the bottom of the closure page: \text{Swap govdef = dpgsave ;}
Figure 1: Standard GTAP Model

GTAP Standard Model
Income-Expenditure-Global Accounts

- **Income**
  - Regional Household
  - Expenditure

- **Private Household** Expenditure (VDPA)
  - Income
  - Taxes

- **Government** Expenditure (VDGA)
  - Income
  - Taxes

- **Intermediates (VFM)**
  - Firms
  - Endowment Factors (EVOM)

- **Imports (VIMS)**
  - Trade
  - Exports (VXMS)

- **Global Bank**
  - Global Savings
  - Global Investment

- **Global Transport**
  - Purchased Services
  - Transportation

Source
Walmsley and Minor 2012; Based on Brockmeier 1996.
Figure 2: MyGTAP Model with Remittances, Foreign Aid and Transfer

Source
Walmsley and Minor 2012
Private households receive income from factors (EVOAH) less depreciation (VDEPH), plus net foreign labor remittances (REMIH and REMOH) and foreign capital income (FYIH and FYOH), transfers between households (TRNH) and from the government (TRNG) (Equation 5).

\[
\text{HHLDINC}(h,r) = \sum(i, ENDW_{COMM}, EVOAH(i,h,r)) - VDEPH(h,r) + REMIH(h,r) - REMOH(h,r) + FYIH(h,r) - FYOH(h,r) + \sum(k, HHLD, TRNH(k,h,r) - TRNH(h,k,r)) + TRNG(h,r)
\]

Where \( r \in \text{REG} \)

\( h \in \text{HHLD} \)

Each private household’s income is then allocated to private consumption and savings using Cobb Douglas as in the standard GTAP model.

Regional savings is calculated as the sum of private household savings and government savings (equation 6) and allocated across investment in the same way as the GTAP model. Note that the value of savings is no longer the same as that in the standard GTAP Data Base, because remittances and other foreign transfers have altered incomes, while expenditures on commodities remain the same. Savings is adjusted to ensure balance between income and expenditures.

\[
\text{SAVE}(r) \ast qsave(r) = \text{SAV}_\text{GOV}(r) \ast qgsave(r) + \sum(h, HHLD, SAV\_HHLD(h,r) \ast qhsave(h,r))
\]

**Inter-regional transfers**

As discussed above a number of additional headers have been included in the GTAP Data Base to facilitate tracking of foreign ownership of factors and the incomes that flows from that ownership (labor/remittances and capital/foreign income); as well as foreign aid. This is based on work undertaken by Sonmez, McDonald and Walmsley (2011)\(^6\).

These foreign income flows are not bilateral, instead flows in and out of a country/region are provided. As a result assumptions need to be made regarding how these flows change as a

---

\(^6\) Further work will be undertaken over the next year to draw in more of the data discussed in this paper.
result of a shock. Below we explain how this is done in the standard closure; shift variables are included so that these assumptions can be changed.7

**Remittances**

Remittances flowing out of a country (remoh) are assumed to change with average wages of skilled and unskilled labor (psh) and any changes in the endowment of labor (qoh) (Equation 7).8 The remittances in (remih) of every country then adjusts (by equation 8) to ensure that total remittances “in” equal total remittances “out” (Equations 9). Equation 9 determines remavi and all remittances in (remih) change by the average equation 8).9

\[
\text{remoh}(h,r) = \text{sum}(i, \text{ENDWL\_COMM}, \text{SHRLAB}(i,h,r) \ast [\text{psh}(i,h,r) + \text{qoh}(i,h,r)]) + \text{sremoh}(h,r) + \text{remavo} \tag{7}
\]

\[
\text{remih}(h,r) = \text{remavi} + \text{sremih}(h,r) \tag{8}
\]

\[
\text{sum}(h, \text{HHLD}, \text{sum}(r, \text{REG}, \text{REMI}(h,r) \ast \text{remih}(h,r))) = \text{sum}(h, \text{HHLD}, \text{sum}(r, \text{REG}, \text{REMO}(h,r) \ast \text{remoh}(h,r))) \tag{9}
\]

By altering the closure remittances out can be fixed10 or remittances in can be fixed and remittances out adjust to again ensure that total remittances in equal total remittances out.11

**Foreign Income**

Foreign income in and out is determined in the same way, although capital and rental rates are used to determine foreign income out rather than wages and labor supply (equations 10-12).

\[
\text{fyoh}(h,r) = \text{sum}(i, \text{ENDWC\_COMM}, \text{SHRCAP}(i,h,r) \ast [\text{psh}(i,h,r) + \text{qoh}(i,h,r)]) + \text{sfyoh}(h,r) + \text{fyavo} \tag{10}
\]

\[
\text{fyih}(h,r) = \text{fyavi} + \text{sfyih}(h,r) \tag{11}
\]

\[
\text{sum}(h, \text{HHLD}, \text{sum}(r, \text{REG}, \text{FYI}(h,r) \ast \text{fyih}(h,r))) = \text{sum}(h, \text{HHLD}, \text{sum}(r, \text{REG}, \text{FYO}(h,r) \ast \text{fyoh}(h,r))) \tag{12}
\]

**Foreign Aid**

Foreign income in and out is determined in the same way, although government income is used to determine movements in foreign aid out (equations 13-15).

---

7 See Appendix 2 for the standard closure and some example alternative closures.
8 Variables sremoh and remavo are exogenous and equal to zero in the standard closure.
9 Variable sremih is exogenous and equal to zero in the standard closure.
10 Swap sremoh = remoh;
11 Swap remavi = remavo and Swap sremih = remih;
aidout(r) = gincome(r) + saidout(r) + aidavo \hspace{1cm} (13)

aidin(r) = aidavi + saidin(r) \hspace{1cm} (14)

\sum(r, \text{REG}, \text{AIDI}(r) \times \text{aidin}(r)) = \sum(r, \text{REG}, \text{AIDO}(r) \times \text{aidout}(r)) \hspace{1cm} (15)

**Multiple Households and Endowments**

As can be seen above, equations relating to private household income (equation 5), foreign income and remittances are allocated across households. The GTAP Data Base does not recognize multiple households, and hence there is only one private household (again, figure 1 illustrates the regional household in the standard GTAP model. All factor incomes accrue and all consumption and savings is undertaken by that one household, which we label the “Main Household” for the purposes of this model.\(^\text{12}\) Multiple households can be added to one country or region of the GTAP database using the MyGTAP Data program.\(^\text{13}\)

A number of changes are required to the model to include multiple households including: a) tracking of household factor supply and household ownership of factor endowments (income) and possible unemployment of those factors; b) the need to allow for additional endowment types; c) the need to accommodate transfers between households and to government; and d) the possibility of differential income and commodity taxes.

Each household now supplies endowments to firms. Hence the total supply of each endowment is the sum of the endowments supplied by all households (equation 16). This also means that we know the ownership of capital by households \((k_{bh})\) and hence can reduce household income by the appropriate amount of depreciation (equation 5).

\[ q_o(i,r) = \sum(h, \text{HHLD}, \text{SHREVOMH}(i,h,r) \times q_{oh}(i,h,r)) \hspace{1cm} (16) \]

In order to incorporate unemployment closures we also include equations 17 and 18. \(\text{emplh}(i,h,r)\) and \(\text{empl}(i,r)\) allow for us to consider employment on labor supplied by particular households or all households equally.

\[ q_{oh}(i,h,r) = q_{oh\_s}(i,h,r) + \text{semplh}(i,h,r) \hspace{1cm} (17) \]

\[ \text{semplh}(i,h,r) = \text{emplh}(i,h,r) + \text{empl}(i,r) \hspace{1cm} (18) \]

\(^{12}\) Note that this Main household is not the Regional Household discussed in Hertel (1997) because it is a private household. The GTAP regional household collects all income and allocates it to both private household and government consumption and savings. In contrast, Main household in MyGTAP simply aggregates all private households, excluding government transactions (see figure 2).

\(^{13}\) Note that this program produces a large number of zeros, for example when a household or endowment does not exist for a particular region. This can cause some structural singularity issues in the model. Appendix 3 contains a note explaining what was done to overcome these issues.
As in the standard GTAP model once the supply of each endowment \((q_0(i,r))\) is determined this endowment moves easily or sluggishly between sectors depending on whether it is defined as a mobile or sluggish endowment.

The MyGTAP Data program also allows the user to split endowments, since the existence of multiple households may also necessitate the need to separate, not just the supply, but also the demand for endowments. For example rural and urban households both supply unskilled workers, however it is unlikely that these are easily substitutable and hence the user may want to separate the demand for rural unskilled and urban unskilled so as to reduce the substitutability between them (creating two prices which move independently in the processes). This is all achieved using the MyGTAP Data program. Once the endowments are split in the data and the endowment set extended, the standard GTAP equations still hold and no changes are required to the underlying model.

The model also includes a number of additional variables to accommodate potential income transfer between households and differential taxes. Two transfers are included in the database and model, transfers between households \(TRNH(k,h,r)\) is the transfer from household \(k\) to household \(h\) in region \(r\); and transfers from household \(h\) to the government \(TRNG(h,r)\). The user can specify the value of transfers in the MyGTAP Data program, otherwise they are assumed to be zero. In the model these transfers are assumed to be exogenous. Income taxes \((toh)\) and commodity taxes \((tpdh \text{ and } tpmh)\) are also included to allow for differences in tax rates paid by households.

**Private Household Expenditure**

The model is set up so that the user can define whether they want to use constant difference of elasticity (CDE) or linear expenditure system (LES) to determine household consumption of each commodity\(^{14}\). This means that in developed economies where the Frisch parameter is one, the user can opt to keep GTAP’s CDE, while imposing the LES in other regions where subsistence is important.

The user defines the use of CDE or LES through a binary parameter \((PRIVTYPE)\) which is read in from the GTAPPARM file (default.prm). In the MyGTAP Data program this takes the value of 1 for the special country where LES is to be used, and zero in all other countries.\(^{15}\).

The set \(REG\_LES\) of countries for which the LES system applies is divided into two subsets:

\[
\text{Set } REG\_LES \# \text{ Countries for which the LES system applies}\#
\]

\[
= \{\text{all}, r, \text{REG}: PRIVTYPE(r) > 0\};
\]

---

\(^{14}\) See Hertel (1997) for an explanation of the CDE function used in GTAP.

\(^{15}\) This is similar to the parameter SLUG which is used for determining sluggish verses mobile endowments.
Set REG_CDE # Countries for which the CDE system applies#
= (all, r, REG: PRIVTYPE(r)=0);

First, regardless of the choice of specification, total private consumption expenditure ($yph(h,r)$) is determined by a Cobb Douglas function as private household income is allocated across private consumption and household savings in a similar way to which it is determined in the standard GTAP model, albeit at the household level (Equation 19).

$$yph(h,r) - poph(h,r) = [pprivh(h,r) + UELASPRIV(h,r) \times uph(h,r)]$$ (19)$^{16}$

**CDE**

In countries where the CDE is used the traditional CDE equation in the standard GTAP model applies with two important differences (Equation 20). First, the equation only applies to the subset of regions REG_CDE; and second, household private expenditure ($yph(h,r)$) is being allocated across commodities not total private expenditure of the regional household ($yp(r)$ in standard GTAP).

$$qph(i,h,r) - poph(h,r) = \sum(k, TRAD_COMM, EP(i,k,h,r) \times pph(k,h,r)) + EY(i,h,r) \times [yph(h,r) - poph(h,r)]$$ (20)

where $r \in$ REG_CDE

**LES**

The code used to incorporate LES for the REG_LES subset of countries is adapted from the Orani model developed by Dixon, Parmenter, Sutton and Vincent (1982). An extract of the code taken from the model is shown in Appendix 4.

First two parameters must be added to the MyGTAP model tab file:

1. The Frisch LES 'parameter' ($FRISCH(h,r)$) is calibrated from the income elasticity and household consumption shares$^{17}$ or read in from the parameters file, if the header exists:

$$FRISCH(h,r) = \sum(c, TRAD_COMM, CONSHR(c,r) \times EY(c,h,r) \times [1.0 - CONSHRH(c,h,r) * EY(c,h,r)]) / [EP(c,c,h,r) + CONSHRH(c,h,r) * EY(c,h,r))]$$ (21)

2. Household expenditure elasticities ($EPS(i,h,r)$) are set equal to the income elasticities also used in the CDE or read in from the parameters file, if the header exists.

$^{16}$ Note that UELASPRIV, the elasticity of private expenditure with respect to income is initially equal to 1 and is endogenous under both the LES and CDE specification. Under the CDE, this elasticity adjusts to reflect changes in the elasticity resulting from changes in income and the allocation of income across commodities with differing income elasticities. For more information on this see McDougall, XXXX. In the LES specification this elasticity remains unchanged.

$^{17}$ Calibration equations used are based on those taken from the CRUSOE suite developed by Mark Horridge. http://www.monash.edu.au/policy/crusoe.htm Note we also include an assertion that all FRISCH parameters are less than -1.8 for REG_LES countries.
\[ EPS(c,h,r) = EY(c,h,r) \quad (22) \]

These parameters can then be used to determine the average (equation 23) and marginal (equation 24) share of luxury goods in total expenditure:

\[ SHR\_LUX(i,h,r) = EPS(i,h,r)/ABS[FRISCH(h,r)] \quad (23) \]
\[ BETA\_LUX(i,h,r) = EPS(i,h,r) \times CONSRH(i,h,r) \quad (24) \]

With the share of luxury goods in total expenditure known from equations (23) and (24) and total consumption expenditure determined by Equation (19) it is then a matter of determining how this income will be divided across subsistence \((qph\_sub(i,h,r))\) and luxury \((qph\_lux(i,h,r))\) consumption. Total consumption \((qph(i,h,r))\) then depend on the sum of these two demands for subsistence and luxury commodities (equation 25).

\[ qph(i,h,r)=SHR\_LUX(i,h,r)*qph\_lux(i,h,r)+(1-HR\_LUX(i,h,r))*qph\_sub(i,h,r) \quad (25) \]

Following the LES methodology, subsistence consumption \((qph\_sub(i,h,r))\) remains constant and only changes with changes in the population or number of households \((poph(h,r))\) and any taste changes \((asub(i,h,r))\). This is shown in equation 26.

\[ qph\_sub(i,h,r) = poph(h,r) + asub(i,h,r) \quad (26) \]

Consumption of luxury commodities \((qph\_lux(i,h,r))\) then depends on private expenditure left over for luxury consumption \((yph\_lux(h,r))\), prices \((pph(i,h,r))\) and a taste parameter \((alux(i,h,r))\): Equation 27.

\[ qph\_lux(i,h,r) + pph(i,h,r) = yph\_lux(h,r) + alux(i,h,r) \quad (27) \]

In order to determine how much of private expenditure is left for luxury goods \((yph\_lux)\) after the subsistence goods have been purchased we simply need to ensure that we are on our budget constraint (equation 28). That is, we need to ensure that total expenditure \((yph,\) determined by equation 19) equals the sum of expenditures on all commodities, which depends on real consumption \((qph,\) determined by equation 25) and prices \((pph)\).

\[ yph(h,r) = \sum(i, TRAD\_COMM, CONSRH(i,h,r) \times (qph(i,h,r) + pph(i,h,r))) \quad (27) \]

**Other Issues and areas of future development**

A number of other changes were made to the model including allowing for Region specific armingtons using the ifheaderexits command in Gempack; changes to population and finally the welfare decomposition was removed.
Armingtons

The implementation region-specific armingtons in the tab file is shown in the box below. First ESUBD_R, the standard GTAP region-generic elasticity is defined and read into the model from the GTAP Data Base. Next a region-specific elasticity is defined. This is initially set equal to the region-generic, unless an additional header exists (if header exists), “ESDR” containing region-specific details.

\[
\text{Coefficient (parameter)}(\text{all,}i,\text{TRAD\_COMM})
\]
\[
\text{ESUBD\_R}(i)
\]
\# region-generic el. of sub. domestic/imported for all agents #;

\text{Read}
\[
\text{ESUBD\_R from file GTAPPARM header "ESBD"};
\]

\[
\text{Coefficient (all,}i,\text{TRAD\_COMM})(\text{all,}r,\text{REG})
\]
\[
\text{ESUBD}(i,r)
\]
\# region-specific el. of sub. among imports of i in Armington structure #;

\text{Formula (all,}i,\text{TRAD\_COMM})(\text{all,}r,\text{REG})
\[
\text{ESUBD}(i,r) = \text{ESUBD\_R}(i) ;
\]

\text{Read (if header exists)}
\[
\text{ESUBD from file GTAPPARM header "ESDR"};
\]

In order to obtain region specific armingtons, the user can include them themselves directly in the parameters file or they can modify flexagg to aggregate the GTAP elasticities using region-specific weights. By using region-specific weights, the aggregated elasticities would differ across regions.

Population

The percentage change in the population by household (poph(r)) is included in the model as an exogenous variable. Since only the total population is known from the GTAP Data Base and not the populations of each household type, we cannot determine the percentage change in the total population from the changes by population; hence the percentage change in the total population (pop(r)) is removed from the model. This means that ug(r) is no longer defined as a per capita variable and hence we re-label it qgov(r) to show that it is now defined as real government expenditure. At this stage we do not have any equations related to migration of people between households.

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18 The code is also adjusted in a similar way for the elasticity of substitution between imports from different regions.
19 There are plans to include this in the GTAPAgg program.
Welfare

Since the regional household has been removed the current welfare decomposition needs to be revised.\textsuperscript{20} For the time being it has been removed.

\textsuperscript{20} This is on the list for future work.
# Appendixes

## APPENDIX 1: LIST OF VARIABLES AND COEFFICIENTS

### Coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOVINC(r)</td>
<td>Income earned by government in region r</td>
<td>REG</td>
</tr>
<tr>
<td>AIDI(r)</td>
<td>Value of foreign aid flowing into region r</td>
<td>REG</td>
</tr>
<tr>
<td>AIDO(r)</td>
<td>Value of foreign aid flowing out of region r</td>
<td>REG</td>
</tr>
<tr>
<td>TTAX(r)</td>
<td>Tax receipts in region r</td>
<td>REG</td>
</tr>
<tr>
<td>HHLDCINC(h,r)</td>
<td>Income earned by household h in region r</td>
<td>HHL,REG</td>
</tr>
<tr>
<td>EVOAH(i,h,r)</td>
<td>Value of income on endowment i owned by household h in region r</td>
<td>ENDW,HHL,REG</td>
</tr>
<tr>
<td>VDEPH(h,r)</td>
<td>Value of capital depreciation on capital owned by household h in region r</td>
<td>HHL,REG</td>
</tr>
<tr>
<td>REMIH(h,r)</td>
<td>Value of remittances in to household h in region r</td>
<td>HHL,REG</td>
</tr>
<tr>
<td>REMOH(h,r)</td>
<td>Value of remittances out of household h in region r</td>
<td>HHL,REG</td>
</tr>
<tr>
<td>FYIH(h,r)</td>
<td>Value of Foreign income received on capital owned by household h in region r</td>
<td>HHL,REG</td>
</tr>
<tr>
<td>FYOH(h,r)</td>
<td>Value of Foreign income paid by household h in region r</td>
<td>HHL,REG</td>
</tr>
<tr>
<td>SAVE(r)</td>
<td>Total Regional savings</td>
<td>REG</td>
</tr>
<tr>
<td>SAV_GOV(r)</td>
<td>Government Saving in region r</td>
<td>REG</td>
</tr>
<tr>
<td>SAV_HHLD(h,r)</td>
<td>Savings by Household h in region r</td>
<td>HHL,REG</td>
</tr>
<tr>
<td>SHRLAB(i,h,r)</td>
<td>Share of labor i in total labor in household h in region r</td>
<td>LAB,HHL,REG</td>
</tr>
<tr>
<td>SHRCAP(i,h,r)</td>
<td>Share of capital i in total capital in household h in region r</td>
<td>ENDW,HHL,REG</td>
</tr>
<tr>
<td>SHREVOMH(i,h,r)</td>
<td>Share of household h in value of endowment i in region r</td>
<td>ENDW,HHL,REG</td>
</tr>
<tr>
<td>ESUBD_R(c)</td>
<td>Region-generic elasticity of substitution between domestic/imported goods for all agents</td>
<td>TRAD</td>
</tr>
<tr>
<td>ESUBM_R(c)</td>
<td>Region-generic elasticity of substitution among imports of i in Armington structure</td>
<td>TRAD</td>
</tr>
<tr>
<td>ESUBD(c,r)</td>
<td>Region-specific elasticity of substitution between domestic/imported goods for all agents</td>
<td>TRAD,REG</td>
</tr>
<tr>
<td>ESUBM(c,r)</td>
<td>Region-specific elasticity of substitution among imports of i in Armington structure</td>
<td>TRAD,REG</td>
</tr>
</tbody>
</table>

### New variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>gincome(r)</td>
<td>Government income in region r</td>
<td>REG</td>
</tr>
<tr>
<td>gincomeslack(r)</td>
<td>Slack variable in the expression for government income</td>
<td>REG</td>
</tr>
<tr>
<td>DGOVBTBAL(r)</td>
<td>CHANGE in the government surplus/deficit in region r</td>
<td>REG</td>
</tr>
<tr>
<td>qgsave(r)</td>
<td>Real Government saving/deficit in region r</td>
<td>REG</td>
</tr>
</tbody>
</table>

21 Unless otherwise stated these variables are percentage changes in.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Endogenous/Exogenous</th>
</tr>
</thead>
<tbody>
<tr>
<td>dp_gav(r)</td>
<td>average distribution parameter shift for Government in region r</td>
<td>Endogenous</td>
</tr>
<tr>
<td>dp_gsave(r)</td>
<td>government saving distribution parameter in region r</td>
<td>Exogenous</td>
</tr>
<tr>
<td>govttrans(r)</td>
<td>transfers from government to household h</td>
<td>Exogenous</td>
</tr>
<tr>
<td>c_TRNG(h,r)</td>
<td>value of transfers from government to household h (levels variable)</td>
<td>Endogenous</td>
</tr>
<tr>
<td>realTRNG(h,r)</td>
<td>value of transfers from government to household h relative to government income (change)</td>
<td>Exogenous</td>
</tr>
<tr>
<td>hhldincome(h,r)</td>
<td>Income of household h in region r net of depreciation</td>
<td>Endogenous</td>
</tr>
<tr>
<td>hincomeslack(h,r)</td>
<td>slack variable in the expression for regional income</td>
<td>Exogenous</td>
</tr>
<tr>
<td>qhsave(h,r)</td>
<td>Real Savings by Household h in region r</td>
<td>Endogenous</td>
</tr>
<tr>
<td>dpbsave_all(r)</td>
<td>Household saving distribution parameter applied to all households equally</td>
<td>Exogenous</td>
</tr>
<tr>
<td>psh(i,h,r)</td>
<td>supply price of endowment i in region r owned by household h</td>
<td>Endogenous</td>
</tr>
<tr>
<td>qoh(i,h,r)</td>
<td>supply of endowment i in region r owned by household h</td>
<td>Endogenous</td>
</tr>
<tr>
<td>hhldtrans(k,h,r)</td>
<td>transfer from household h1 to household h2 in region r</td>
<td>Exogenous</td>
</tr>
<tr>
<td>c_TRNH(h1,h2,r)</td>
<td>value of transfers from h1 to h2 in region r (levels, change)</td>
<td>Endogenous</td>
</tr>
<tr>
<td>realTRNH(h1,h2,r)</td>
<td>value of transfers from h1 to h2 in region r relative to household income (change)</td>
<td>Exogenous</td>
</tr>
<tr>
<td>remoh(h,r)</td>
<td>Remittances out of household h in region r</td>
<td>Endogenous</td>
</tr>
<tr>
<td>sremoh(h,r)</td>
<td>Shifter to change the rate of remittances out</td>
<td>Exogenous</td>
</tr>
<tr>
<td>remavo</td>
<td>Average rate of remittances out</td>
<td>Exogenous</td>
</tr>
<tr>
<td>remih(h,r)</td>
<td>Remittances into household h in region r</td>
<td>Endogenous</td>
</tr>
<tr>
<td>sremih(h,r)</td>
<td>Shifter to change the rate of remittances in</td>
<td>Exogenous</td>
</tr>
<tr>
<td>remavi</td>
<td>Average rate of remittances in</td>
<td>Endogenous</td>
</tr>
<tr>
<td>fyoh(h,r)</td>
<td>Foreign income out of household h in region r</td>
<td>Endogenous</td>
</tr>
<tr>
<td>sfyoh(h,r)</td>
<td>shifter Foreign income out household h in region r</td>
<td>Exogenous</td>
</tr>
<tr>
<td>Fyavo</td>
<td>Average Foreign income out household h in region r</td>
<td>Exogenous</td>
</tr>
<tr>
<td>fyih(h,r)</td>
<td>Foreign income in household h in region r</td>
<td>Endogenous</td>
</tr>
<tr>
<td>sfyih(h,r)</td>
<td>shifter Foreign income in household h in region r</td>
<td>Exogenous</td>
</tr>
<tr>
<td>fyavi</td>
<td>Average Foreign income into household</td>
<td>Endogenous</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td>h in region r</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td><strong>Foreign Aid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>aidout(r)</td>
<td>REG Foreign aid out of region r</td>
<td></td>
</tr>
<tr>
<td>saidout(r)</td>
<td>REG shifter on aid out of region r</td>
<td></td>
</tr>
<tr>
<td>Aidavo</td>
<td>Average Foreign aid out</td>
<td></td>
</tr>
<tr>
<td>aidin(r)</td>
<td>REG Foreign aid in region r</td>
<td></td>
</tr>
<tr>
<td>saidin(r)</td>
<td>REG shifter on aid into region r</td>
<td></td>
</tr>
<tr>
<td>aidavi</td>
<td>Average Foreign aid in</td>
<td></td>
</tr>
<tr>
<td><strong>Endowment Supply</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>qoh_s(i,h,r)</td>
<td>ENDW,HHLD,REG supply of endowment i from household h in region r (including unemployed)</td>
<td></td>
</tr>
<tr>
<td>semplh(i,h,r)</td>
<td>ENDW,HHLD,REG employment of endowment i from household h in region r</td>
<td></td>
</tr>
<tr>
<td>emplh(i,h,r)</td>
<td>ENDW,HHLD,REG shifter on employment of endowment i from household h in region r</td>
<td></td>
</tr>
<tr>
<td>empl(i,r)</td>
<td>ENDW,REG shifter on employment of endowment i in region r (equal across all households)</td>
<td></td>
</tr>
<tr>
<td><strong>Population</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>poph(h,r)</td>
<td>HHLD,REG Population by household h in region r</td>
<td></td>
</tr>
<tr>
<td><strong>Taxes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tpdh(c,h,r)</td>
<td>TRAD,HHLD,REG commodity-, source-, and household-specific shift in tax on private consumption of domestic commodity c in region r by household h</td>
<td></td>
</tr>
<tr>
<td>tpmh(c,h,r)</td>
<td>TRAD,HHLD,REG commodity-, source-, and household-specific shift in tax on private consumption of imported commodity c in region r by household h</td>
<td></td>
</tr>
<tr>
<td>toh(i,h,r)</td>
<td>ENDW,HHLD,REG income tax in region r on endowment i owned by household h</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 2: THE STANDARD CLOSURE AND SOME ALTERNATIVE CLOSURE SWAPS

Standard Closure

<table>
<thead>
<tr>
<th>Exogenous</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>poph</td>
<td>Supply of Endowments</td>
</tr>
<tr>
<td>qoh_s</td>
<td>Numeraire</td>
</tr>
<tr>
<td>Pfactwld</td>
<td>Slack variables</td>
</tr>
<tr>
<td>psaveslack profitslack incomeslack</td>
<td></td>
</tr>
<tr>
<td>endwslack cgdslasslack tradslack</td>
<td>Technological change variables</td>
</tr>
<tr>
<td>gincomeslack hincomeslack</td>
<td></td>
</tr>
<tr>
<td>ams atm atf ats atd</td>
<td></td>
</tr>
<tr>
<td>aasec aoreg avasec aavereg</td>
<td></td>
</tr>
<tr>
<td>afcom afsec aareg afecon aafereg</td>
<td></td>
</tr>
<tr>
<td>aoall aall afeall</td>
<td></td>
</tr>
<tr>
<td>dp_priv dp_gov dp_save dp_save_all</td>
<td>Distribution parameters</td>
</tr>
<tr>
<td>to tp tm tx ts tp dh tp mh toh</td>
<td>Tax instruments</td>
</tr>
<tr>
<td>emplh empl</td>
<td>Employment variables</td>
</tr>
<tr>
<td>sremoh sremih remavo</td>
<td>Remittance shifters</td>
</tr>
<tr>
<td>sfyo h sf yh fyavo</td>
<td>Foreign income shifters</td>
</tr>
<tr>
<td>saidout saidin aidavo</td>
<td>Foreign aid shifters</td>
</tr>
<tr>
<td>realTRNG realTRNH</td>
<td>Transfers between households and government</td>
</tr>
</tbody>
</table>

Long run Closure

\[
\text{swap } qoh_s(ENDWC\_COMM, HHLD, REG) = \text{expand}(ENDWC\_COMM, HHLD, REG); 
\]

Closures related to Remittances, Foreign Income and Foreign Aid etc

Fix outward remittances, foreign income and foreign aid respectively

\[
\text{swap sremoh = remoh ;} 
\]

\[
\text{swap sfyoh = fyoh ;} 
\]

\[
\text{swap saidout = aidout ;} 
\]

Increase remittances in by 10%

\[
\text{swap sremih = remih ;} 
\]

\[
\text{swap remavo = remavi ;} 
\]
shock remih = uniform 10;

**Fixed Government Balance relative to Government Income**

swap DGOVTBALR = dpgsave ;

**Fixed Real Government Saving**

swap qgsave = dpgsave ;

**Shock Government and Household Transfers**

*Household Transfers (change in nominal):*

swap realTRNH("hapr","hanp","Tanzania") = c_TRNH("hapr","hanp","Tanzania") ;

shock c_TRNH = uniform 1;

*Household Transfers (change in real)*

shock realTRNH("hapr","hanp","Tanzania") = uniform 1;

*Government Transfers (change in nominal):*

swap realTRNG("hapr","Tanzania") = c_TRNG("hapr","Tanzania") ;

shock c_TRNG = uniform 1;

*Government Transfers (change in real)*

shock realTRNG("hapr","Tanzania") = uniform 1;

**Fix the Trade balance relative to Income**

Where savings of all households adjusts equally:

swap DTBALR("Tanzania") = dphsave_all("Tanzania");

Alternatively if just want one household to adjust:

swap DTBALR("Tanzania") = dphsave("MainHHLD","Tanzania");

Where investment adjusts:

swap DTBALR("Tanzania") = cgdsslack("Tanzania");

**Unemployment**

swap empl("UnSkLab",REG) = pfactreal("UnSkLab",REG) ;

swap empl("unsk_rural",REG) = pfactreal("unsk_rural",REG) ;
**APPENDIX 3: A NOTE ON STRUCTURAL SINGULARITY AND ZEROS IN THE DATABASE**

The MyGTAP Data program includes the multiple households and additional endowments for the countries of interest, while the main household and GTAP endowments for the other regions remain unchanged. The reason for this is that substantial data is required to split households and endowments for all countries. This then provides the usual GTAP results for all regions except those where additional data has been incorporated using MyGTAP. Unfortunately this results in a large number of zeros in the database, which will result in structural singularity if modifications are not made. In order to fix this problem of structural singularity the shares where numbers are zero are replaced by the average shares of the main household (Example 1: equation 19 and 20) or of the GTAP endowment to which it is mapped (Example 2: equation 21 and 22). The implications of this are that results are obtained for all households and endowments regardless of whether the data exists. These results are averages because of the use of the average shares. It is up to the user to understand their data and hence know which results should be analyzed and discussed.

**Example 1**

\[
CONSHRH(i,h,r) = \frac{VPAH(i,h,r)}{PRIVEXPH(h,r)}
\]  
(19)

Unless \(PRIVEXPH(h,r)=0\), then:

\[
CONSHRH(i,h,r) = \frac{VPA(i,r)}{PRIVEXP(r)}
\]  
(20)

**Example 2**

\[
SHREVOMH(i,h,r) = \frac{EVOMH(i,h,r)}{sum(k, HHLD, EVOMH(i,k,r))}
\]  
(21)

Unless \(VOM(i,r)=0\), then

\[
SHREVOMH(i,h,r) = \frac{sum(k, ENDW_COMM: MAPENDW(k)=MAPENDW(i), EVOMH(k,h,r))}{sum(k, HHLD, sum(l, ENDW_COMM: MAPENDW(l)=MAPENDW(i), EVOMH(l,k,r)))}
\]  
(22)
APPENDIX 4: LES Code extract

Coefficient (all, h, HHLD)(all, r, REG)
   FRISCH(h, r)
# Frisch LES 'parameter' dependednt on EY, EP and CONSHR #;
Formula (initial)(all, h, HHLD)(all, r, REG)
   FRISCH(h, r) = sum{c, TRAD_COMM, CONSHRH(c, h, r) * EY(c, h, r) *
                  [1.0 - CONSHRH(c, h, r) * EY(c, h, r)]/
                  [EP(c, c, h, r) + CONSHRH(c, h, r) * EY(c, h, r)]};
Read (ifheaderexists) FRISCH from file GTAPDATA header "FRSH";
  ! ifheaderexists used if user wants to specify their own FRISCH parameters.!

Coefficient (all, i, TRAD_COMM)(all, h, HHLD)(all, r, REG)
   EPS(i, h, r) # Household expenditure elasticities -
                  calibrated from EY #;
Formula (initial)(all, c, TRAD_COMM)(all, h, HHLD)(all, r, REG)
   EPS(c, h, r) = EY(c, h, r) ;
Read (ifheaderexists) EPS from file GTAPDATA header "XPEL";
  ! ifheaderexists used if user wants to specify their own EPS parameters.!

Coefficient (all, r, REG)
   CHKFRISCH(r) # Check Frisch Parm of LES country is >-
                  1.8#;
Formula (all, r, REG)
   CHKFRISCH(r) = maxs(h, HHLD, FRISCH(h, r));

Coefficient (integer, parameter)(all, r, REG)
   PRIVTYPE(r) # Use CDE or LES in private consumption #;
Formula (initial)(all, r, REG)
   PRIVTYPE(r) = 0 + if(CHKFRISCH(r)<-1.8, 1) ;
Read (ifheaderexists)
   PRIVTYPE from file GTAPPARM header "PREG";
  ! ifheaderexists used if user wants to specify which countries are to use LES !

Set
   REG_LES # Countries for which the LES system applies#
   = (all, r, REG: PRIVTYPE(r)>0);

Set
   REG_CDE # Countries for which the CDE system applies#
   = (all, r, REG: PRIVTYPE(r)=0);

Assertion (all, h, HHLD)(all, r, REG_LES)
   FRISCH(h, r)<-1.8 ;
Note that if user specifies countries as LES in PREG. But the FRISCH of these countries is > -1.8, then the model will stop. FRISCH should be a large negative for LES countries.

2-2.b Alternate-Household Demand System (LES) for Developing Countries.

Variable (all,h,HHLD)(all,r,REG_LES)
   Utility_LES(h,r) # Utility per household #;

Variable (all,h,HHLD)(all,r,REG_LES)
   yph_lux(h,r) # Household - supernumerary demands #;

Variable (all,i,TRAD_COMM)(all,h,HHLD)(all,r,REG_LES)
   qph_lux(i,h,r) # Household - supernumerary demands of commodity i #;

Variable (all,i,TRAD_COMM)(all,h,HHLD)(all,r,REG_LES)
   qph_sub(i,h,r) # Household - subsistence demands of commodity i #;

Variable (all,i,TRAD_COMM)(all,h,HHLD)(all,r,REG_LES)
   alux(i,h,r) # Taste Change, household luxury demands#;

Variable (all,i,TRAD_COMM)(all,h,HHLD)(all,r,REG_LES)
   asub(i,h,r) # Taste Change, household subsistance demands#;

Variable (all,i,TRAD_COMM)(all,h,HHLD)(all,r,REG_LES)
   s_sub(i,h,r) # Taste change shifter for subsistence #;

Update (change)(all,h,HHLD)(all,r,REG_LES)
   FRISCH(h,r) = FRISCH(h,r) * [yph(h,r) - yph_lux(h,r)]/100.0;

Update(changes)(all,i,TRAD_COMM)(all,h,HHLD)(all,r,REG_LES)
   EPS(i,h,r) = EPS(i,h,r)*[qph_lux(i,h,r)-qph(i,h,r)
     + yph(h,r) - yph_lux(h,r)]/100.0;

Coefficient (all,i,TRAD_COMM)(all,h,HHLD)(all,r,REG_LES)
   SHR_LUX(i,h,r) # (Luxury/total expenditure) #;

Formula (all,i,TRAD_COMM)(all,h,HHLD)(all,r,REG_LES)
   SHR_LUX(i,h,r) = EPS(i,h,r)/ABS[FRISCH(h,r)];
Coefficient (all, i, TRAD_COMM)(all, h, HHLD)(all, r, REG_LES)
   BETA_LUX(i, h, r) # Marginal household budget shares #;

Formula (all, i, TRAD_COMM)(all, h, HHLD)(all, r, REG_LES)
   BETA_LUX(i, h, r) = EPS(i, h, r) * CONSHRH(i, h, r);

Equation E_qlux
# Luxury demand for commodities #
(all, i, TRAD_COMM)(all, h, HHLD)(all, r, REG_LES)
   qph_lux(i, h, r) + pph(i, h, r) = yph_lux(h, r) + alux(i, h, r);

Equation E_qsub
# Subsistence demand for commodities #
(all, i, TRAD_COMM)(all, h, HHLD)(all, r, REG_LES)
   qph_sub(i, h, r) = poph(h, r) + asub(i, h, r);

Equation E_qph
# Total Household demand form composite commodities#
(all, i, TRAD_COMM)(all, h, HHLD)(all, r, REG_LES)
   qph(i, h, r)=SHR_LUX(i, h, r)*qph_lux(i, h, r)+[1-SHR_LUX(i, h, r)]*qph_sub(i, h, r);

Equation E_utility_LES
# Change in utility disregarding taste change terms #
(all, h, HHLD)(all, r, REG_LES)
   utility_LES(h, r) = sum{i, TRAD_COMM, BETA_LUX(i, h, r)*qph_lux(i, h, r)};

Equation E_alux
# Default setting for luxury taste shifter #
(all, i, TRAD_COMM) (all, h, HHLD)(all, r, REG_LES)
   alux(i, h, r) = asub(i, h, r) - sum{k, TRAD_COMM, BETA_LUX(k, h, r)*asub(k, h, r)};

Equation E_asub
# Default setting for subsistence taste shifter #
(all, i, TRAD_COMM)(all, h, HHLD)(all, r, REG_LES)
   asub(i, h, r) = s_sub(i, h, r) - sum{k, TRAD_COMM, CONSHRH(k, h, r)*s_sub(k, h, r)};

Equation E_yph_lux
# Finds yph_lux #
(all, h, HHLD)(all, r, REG_LES)
   yph(h, r) =
      sum(i, TRAD_COMM, CONSHRH(i, h, r) * (qph(i, h, r) + pph(i, h, r)))) ;
References


Sonmez, Y., S. McDonald and T. L. Walmsley, 2011. “Augmenting GTAP Database: Are the data on intra institutional transactions important?”, Presented at the 14th Annual Conference on Global Economic Analysis, Venice, Italy