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METRO VERSION 1 MODEL DOCUMENTATION

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1. MODELLING TRADE AT THE OECD: METRO V1, BASE MODEL

1.1 Introduction

1. The OECD Trade Model, METRO, is a computable general equilibrium (CGE) model derived from the Social Accounting Matrix (SAM) based CGE model GLOBE developed by Scott McDonald, Karen Thierfelder and Terrie Walmsley (2013) using GAMS software. The model is a direct descendant of an early US Department of Agriculture model (Robinson et al., 1990) and NAFTA (Robinson et al., 1993) and follows trade principles from the 1-2-3 model (de Melo and Robinson, 1989; Devarajan et al., 1990). Namely, these models divide an economy into tradable and non-tradable goods and link domestic and world prices through the tradable sectors.[1] The model is calibrated using an augmented Social Accounting Matrix (SAM) version of the GTAP database (for v8 see Narayanan et al., 2012), described in more detail below. The novelty and strength of METRO lies in the detailed trade structure and the differentiation of production and consumption commodities by use – intermediate, household, government and capital consumption. The differentiation of commodity supply, and thus the resulting trade flows, by use category improves the ability to depict and analyse, amongst other things, global value chains (GVCs). In addition this structure allows the modelling of policy instruments targeting specific uses, such as resource-based restrictions, local content requirements, and government consumption.

2. The model is based on a series of regional SAMs, derived from the GTAP database, linked through trade relationships[2]. This database identifies agents (households, production units and government) and serves as a base to which to calibrate the model.[3] In addition, the database contains a series of elasticities, including substitution elasticities governing the interaction of imports or exports and domestic commodities, the Constant Elasticity of Substitution (CES) elasticities of the production functions, income elasticities of demand and the Frisch (marginal utility of income) parameter. Finally, the database contains taxes and tariff information on a national and bilateral basis, respectively.

3. Taking the transactions identified in the SAM database as a starting point, the model represents an economy, as a mix of linear and non-linear relationships. These relationships determine the response to exogenous changes, or shocks, in simulations. For example, households are assumed to maximize utility using a Stone-Geary utility function which allows for subsistence consumption expenditures. This reduces to a Cobb-Douglas function given an appropriate specification of parameters. Agents consume sets of composite commodities, which are formed as three-level CES aggregates of imported and domestically produced goods. The optimal composition is determined by relative prices, following the so called Armington assumption (Armington, 1969) of product differentiation. This 3-stage Armington approach avoids extreme specialization and price fluctuations which are often obtained with other trade assumptions, but bears the shortcoming that small numbers stay small and big numbers remain big, which limits the possibility to model structural changes in trade (i.e., influences the time frame assumed in simulated scenarios).[4]

4. Domestic production is depicted through a three-level nested production process. In the first nest, intermediate demand and value added form output with the possibility of assuming either Leontief or CES technology, with CES being set as the default technology. In the second nest, aggregate intermediate demand is formed by intermediates in fixed proportions using the Leontief technology while value added is aggregated using a CES for the production factors capital, land, natural resources and aggregate labour. On

[1] For more details see Devarajan et al. (1997).

[2] See section 2 for a description of the METRO database.

[3] Calibration is the process in which parameter values are made consistent with the underlying base data.

[4] Structural change can, however, be introduced exogenously in the model.

the third level skilled and unskilled labour form the labour aggregate composite. The vector of commodities available to domestic markets is a function of a nested structure assuming imperfect transformability (CET) between domestic and export markets, the optimal distribution being determined by relative prices.

5. The core model is augmented with modules that can be switched on and off depending on study purposes. The base model is run (calibrated) to determine the initial parameter values. After this, experiments are introduced separately, using data from the base model run. This documentation starts with a more detailed description of the core model in section 1 and continues with the description and development of the database in section 2. The modules with which the model can be augmented are explained in section 3.

1.2 The model structure

6. The model consists of one master GAMS file (GMS) and a series of include files (INC and various other supporting files as listed in Table 1. Data is read into the model using a GAMS Data Display file (GDX) and an excel file. These files contain the basic SAM data (GDX) and definitions of set, variable and parameters names as well as other supporting information (excel file). For control and information, the model produces several GDX files during each run, including the initial calibration run. Figure 1 illustrates the file structure and shows the place where each INC file is called into the core program, together with the titles of each of the sections of the core program file itself.

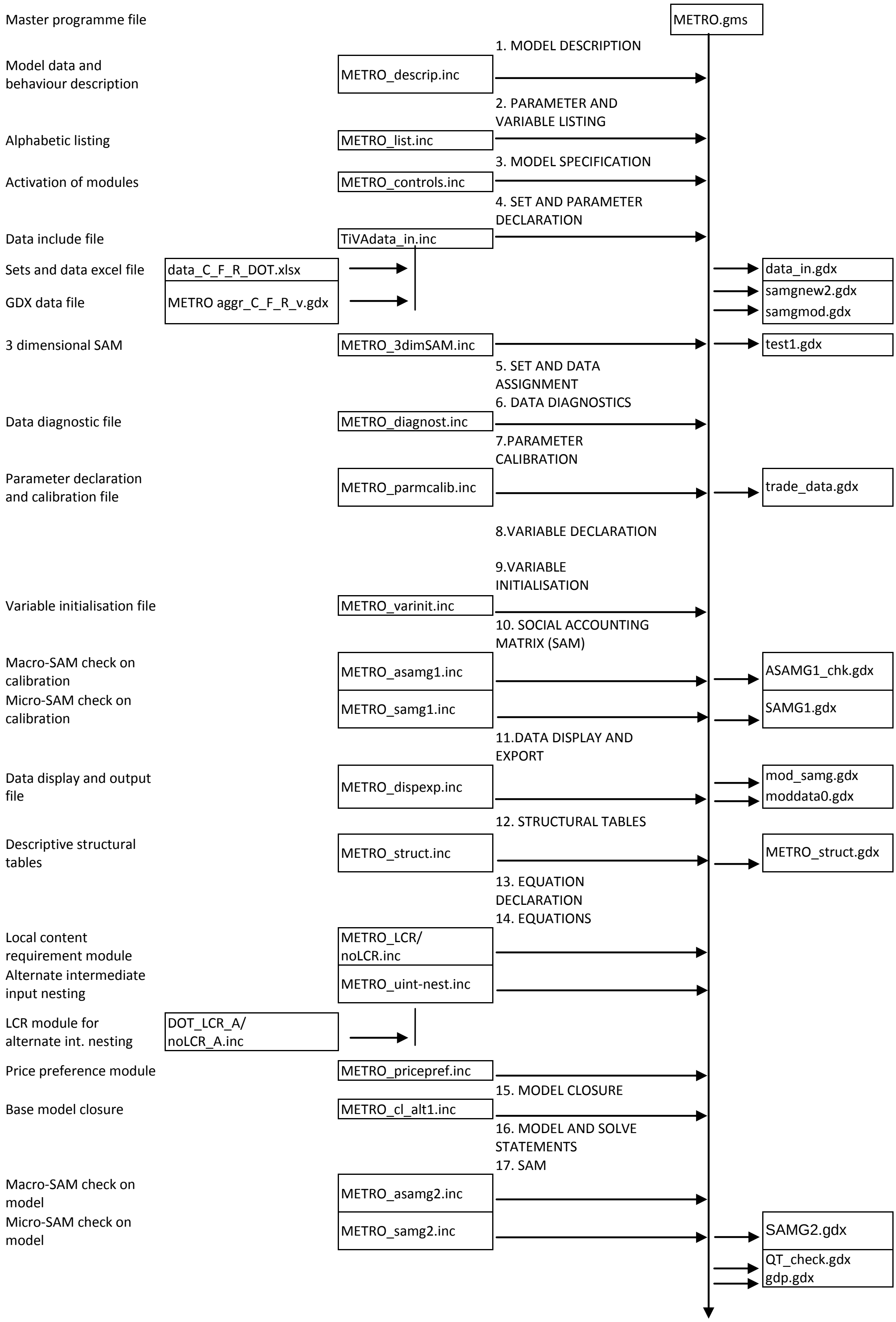
Table 1. Important GAMS file types

GPR	GAMS project file: stores all project information in a specific directory
GMS	GAMS master file
INC	GAMS include file: auxiliary files linked to the GMS master file
GDX	GAMS data exchange file: platform independent, binary data file. GDX files can be used to pass data between GAMS and other programs
LST	GAMS output file: lists all output information, automatically generated
LOG	GAMS output file that contains information relevant to the solution and error status

Source: Authors' compilation.

7. The descriptions down the left hand side of Figure 1 indicate the role each INC file plays in the programme, the right hand side shows resulting outputs via GDX files. The majority of the INC files only need attention if the user is making changes to the core model code. However there are two 'areas' to which the user needs to pay particular attention. The first is the data entry file 'TiVAdata_in.inc' and the second is the module control file 'controls.inc', which are explored in detail in the next section.

Figure 1. Model file structure



Source: Authors' compilation based on McDonald et al. 2013.

1.2.1 The model setup

8. Before each run an appropriate aggregation of the database is chosen and the model is then calibrated to this aggregation.

Database

9. The database, explained in detail in section 2, is aggregated for study purposes using a separate aggregation program. The database enters the model using the data include file 'TiVAdata_in.inc'. In addition to the database, supplied as a GDX file, a version specific excel file supplies the model with set definitions and additional data, such as various elasticities. In order to change an aggregation, the INC and excel files need to be adjusted to be consistent with the new aggregation.

10. By default, trade and production elasticities, based on GTAP data, are supplied in the GDX data file. Alternatively, the modeller can choose to set these elasticities in the sets and data excel file. In addition to the trade and production elasticities, the sets and data excel file contains income, Frisch and factor demand elasticities. This structure allows elasticities to be sourced from either the underlying GTAP database or the user-defined elasticity values in the excel file. The elasticity ultimately applied in the model as well as any related scaling of parameter values that the user may choose is indicated in the 'controls' sheet of the sets and data excel file.

Setting up the model

11. The model allows for different setups of the base structure as well as the application of various scenario-specific modules. The model setup is defined in the 'controls' sheet of the sets and data excel file and the 'controls.inc' INC file. In addition to the choice of elasticity sources and their scaling, the 'controls' sheet of the sets and data excel file defines:

- The target for automatic scaling of the database[5].
- Small import shares for bilateral trade.
- Small import shares on aggregate import level.
- Small export shares.

12. Defining a trade flow as a 'small share', sets its supply as a fixed proportion rather than using CES or CET technology. This avoids large terms of trade effects but allows less flexibility in the structure of trade flows.

13. The different modules are activated in the 'controls.inc' include file. To date these include:

- Alternate intermediate input nesting.
- Local content requirement module.
- Price preference module.

14. Closures rules are defined in a special include file 'METRO_cl_alt1.inc', a detailed description is provided in section 1.4.

5 The database is scaled to improve solver performance.

15. Unemployment is stipulated in the sets and data excel file. Unemployed factor and region pairs are defined in the ‘sets’ sheet and the base unemployment rate is set in the ‘unemp_rate’ sheet. If both, set definition and unemployment rate, are empty there is no unemployment in the model.

1.2.2 Model checks[6]

16. The model comes with a set of automatic basic checks of the database and calibration, if they fail the model run aborts.

17. Whenever the user makes any changes to the model or the model data these checks should be conducted BEFORE carrying out any simulations; failure to do so may mean that the simulations are conducted using an incorrectly specified model.

1. Slack variables: All the slack variables should equal zero, or very nearly zero. Search for ‘var walras, ‘var kapworsys’, ‘var globeslack’ in the LST file– all should be zero. (Note: if the version of GAMS used has indexing for the list file select SolVar and the slacks are reported at the end of the list of variables.)

2. Check the Left hand sides: Search for ‘LHS’ in the LST file, then after finding the first occurrence of ‘LHS’ search for ‘***’. If any equations are incorrectly specified they are identified. (Note: if the version of GAMS used has indexing for the list file select SolEQU and then the first named equation, this will move the cursor to the first equation.)

3. Check data replication: First check the Macro SAM, several test parameters are reported in the LST file: search for ‘ASAMG2CHK’ – all the values should equal 1; then search for and check DIFFASAMG2 and CNTASAMG2 – these should be zeroes or close to zero. Second check the Micro SAM: search for and check DIFFSAMG2 and CNTSAMG2 – these should be zeroes or close to zero. (Note: if the version of GAMS used has indexing for the list file select DISPLAY.)

4. Check the numéraire: In the sets and data excel workbook go to the worksheet ‘mcontrols’ and change the value of ‘numerchk’ to 2, save the excel file and rerun the model. Then check the Macro SAM: search for ‘ASAMG2CHK’ – all the values should equal 2; note that DIFFASAMG2 and CNTASAMG2 are no longer meaningful and therefore the micro SAM calculations have not been implemented. If the model passes all these checks the model will (usually) be correct.

1.3 Formal description of the model

18. The formal description of the model proceeds as follows: section 1.3.1 establishes the overall modelling conventions; section 1.3.2 provides a list of the sets, parameters and variables used in the model; section 1.3.3 provides the details on commodity market structure, including use markets; section 1.3.4 provides the details of the production structure; section 1.3.5 sets out the ‘institutions’ or final demand markets and finally, section 1.3.6 describes the GLOBE region and section 1.3.7 the market clearing conditions.

[6] This section is largely reproduced from McDonald and Thierfelder (2012).

1.3.1 Modelling conventions[7]

19. The equations for the model are set out in 9 'blocks' each of which can contain a number of sub blocks. The equations are grouped under the following headings:

1. TRADE BLOCK
    a. Exports Block
    b. Imports Block
2. COMMODITY PRICE BLOCK
3. NUMERAIRE PRICE BLOCK
4. PRODUCTION BLOCK
    a. Production
    b. Intermediate Input Demand
    c. Commodity Output
    d. Activity Output
5. FACTOR BLOCK
6. HOUSEHOLD BLOCK
    a.Household Income
    b. Household Expenditure
7. GOVERNMENT BLOCK
    a. Government Tax Rates
    b. Government Tax Revenues
    c. Government Income
    d. Government Expenditure Block
8. CAPITAL BLOCK
    a. Savings Block
    b. Investment Block
9. MARKET CLEARING BLOCK
    a. Factor Accounts
    b. Commodity Accounts
    c. Investment and Savings Accounts
    d. Commodity Trade Accounts
    e. Margin Trade Accounts
    f. Absorption Closure
    g. Slack

20. This grouping is carried throughout the model code, i.e., it is followed for the parameter declaration and calibration, variable declaration and variable initialization sections. This modularization of the code is adopted for ease of reading and altering the model rather than being a requirement of the model.

21. A series of conventions are adopted for the naming of variables and parameters. These conventions are not a requirement of the modelling language; rather they are designed to ease reading of the model.

- All VARIABLES are in upper case.

7 This section is largely reproduced from McDonald et al. (2013).

- The standard prefixes for variable names are: *P* for price variables, *Q* for quantity variables, *W* for factor prices, *F* for factor quantities, *E* for expenditure variables, *Y* for income variables, and *V* for value variables
- All variables have a matching parameter that identifies the value of the variable in the base period. These parameters are in upper case and carry a '0' suffix, and are used to initialise variables.
- A series of variables are declared that allow for the equiproportionate multiplicative adjustment of groups of variables. These variables are named using the convention ***ADJ*, where ** is the variable series they adjust.
- A series of variables are declared that allow for the additive adjustment of groups of variables. These variables are named using the convention *D***, where ** is the variable series they adjust.
- All parameters are in lower case, except those paired to variables that are used to initialise variables.
- Parameter names have a two or five character suffix which distinguishes their definition, e.g., ***sh* is a share parameter, ***av* is an average and ***const* is a constant parameter.
- For the Armington (CES) functions all the share parameters are declared with the form *delta***, all the shift/efficiency parameters are declared with the form *ac***, and all the elasticity parameters are declared with the form *rho***, where ** identifies the function in which the parameter operates.
- For the CET functions all the share parameters are declared with the form *gamma***, all the shift/efficiency parameters are declared with the form *at***, and all the elasticity parameters are declared with the form *rho***, where ** identifies the function in which the parameter operates.
- All coefficients in the model are declared with the form *io*****, where **** consists of two parts that identify the two variables related by the coefficient.
- The index ordering follows the specification in the SAM: row, column, and then r to indicate the region. For example, exports from region *r* to region *w* would be $QER_{c,w,r}$ because region *r*'s export data in its SAM is found in the commodity row (*c*) and the trade partner column (*w*). Likewise, imports in region *r* from region *w* are designated, $QMR_{w,c,r}$ because region *r*'s import data in its SAM is found in the trade partner row (*w*) and the commodity column (*c*).
- All sets have another name, or alias, given by the set name followed by '*p*'. For example, the set of commodities may be called *c* or *cp*.

1.3.2 List of sets, variables and parameters

22. Rather than writing out each and every equation in detail it is useful to define a series of sets; thereafter if a behavioural relationship applies to all members of a set an equation only needs to be specified once.

23. The model contains a master set (*sac*) for all the transactions by each region plus a series of sets that group commodities, use categories, activities, factors, import duties, export taxes, trade margins, trade and finally some individual accounts relating to domestic institutions. The outer set for any region contains basic sets used in the model and data sets which are used to read in data. Data which are read into the model with data set dimensions are transformed into basic set dimensions during the data organization process.

24. The following Tables 2 to 6 contain full lists of sets, variables and parameters in alphabetical order. In addition, Table 7 provides additional variables and parameters applied in the specific modules that accompany the core model.

Table 2. List of sets

sac(*)	SAM accounts, master set		
Basic sets for each region in this model:			
c(sac)	Commodity accounts	*tff(sac)*	Factor tax account
u(sac)	Use category	*tss(sac)*	Sales tax account
a(sac)	Activity accounts	*h(sac)*	Household accounts
ff(sac)	Factors and aggregates	*g(sac)*	Government accounts
tmr(sac)	Ad valorem tariff accounts	*i(sac)*	Investment accounts
tmrs(sac)	Specific tariff accounts	*owatpmarg(sac)*	Trade and transportation margins
ter(sac)	Export subsidy accounts	*w(sac)*	Rest of world trade partners
Database sets – only used in calibration phase:			
mc(sac)	Import commodities	*tsu(sac)*	Sales tax by use category
dc(sac)	Domestic commodities	*wwu(sac)*	RoW trade partners by use category
tmu(sac)	Tariff accounts by use category	*wwugn(wwu)*	wwu without GLOBE region
teu(sac)	Export subsidy by use category		
Subsets specified by the user (in excel sheet)			
Subsets of c		Subsets of ff:	
cagr(c)	Agricultural commodities	*f(ff)*	Natural factor accounts
cnat(c)	Natural resource commodities	*fag(ff)*	Aggregate factors
cfd(c)	Food commodities	*f2(ff)*	Factor inputs to QVA at level 1
cind(c)	Industrial commodities	*l(f)*	Labour Factors
ccns(c)	Construction commodities	*ls(l)*	Skilled Labour Factors
cuti(c)	Utility commodities	*lu(l)*	Unskilled Labour Factors
cser(c)	Service commodities	*k(f)*	Capital Factors
cagg	Aggregate commodity groups	*lnd(f)*	Land factors
subsets of a:		*uef(f,r)*	Unemployed factors by region
aagr(a)	Agricultural activities	*Subsets of w:*	
anat(a)	Natural resource activities	*wagg*	Aggregate region groups
afd(a)	Food activities	*wgn(w)*	Rest of world without Globe
aind(a)	Industrial activities		
acns(a)	Construction activities		
auti(a)	Utility activities		
aser(a)	Service activities		
aagg	Aggregate activity groups		

Table 2. List of sets (continued)

Dynamic sets: Various subsets of a, c and r are declared and then assigned on the basis of certain characteristics of the data set used to calibrate the specific implementation of the model			
subsets of c:		Subsets of a:	
ct(c,r)	Trade margin commodities	*acx(a,r)*	Activities purchased domestically
ctn(c,r)	Non trade margin commodities	*acxn(a,r)*	Activities NOT purchased domestically
ct2(c)	Trade margin commodities	*aqx(a,r)*	Activities and regions with CES fn at Level 1
ctn2(c)	Non trade margin commodities	*aqxn(a,r)*	Activities and regions with Leontief fn at Level 1
ce(c,u,r)	Export commodities	*aleon(a)*	Activities with Leontief top level prodn function
cen(c,u,r)	Non-export commodities	set of regions, r, and its subsets:	
cer(c,u,w,r)	Export commodities by region	*r*	SAM regions
cern(c,u,w,r)	Non-export commodities by region	*ragg*	Aggregate region groups
cm(c,u,r)	Imported commodities	*rgn(r)*	SAM Regions without Globe
cmn(c,u,r)	Non-imported commodities	*ref(r)*	Reference region
cmr(w,c,u,r)	Imported commodities by region	*rleon(r)*	Regions with Leontief top level prodn function
cmrn(w,c,u,r)	Non-imported commodities by region	sets for remittances:	
cmrs(w,c,u,r)	Small shares imported commodities by region	*ror(w,h,r)*	remittances outflows by partner region
cmrsn(w,c,u,r)	Non-small shares imported commodities by region	*ror(w,h,r)*	no remittance outflows
cms(c,u,r)	Commodities with small shares	*rir(h,w,r)*	remittances inflows by partner region
cmrl(w,c,u,r)	Large shares imported commodities by region	*rir(h,w,r)*	no remittance inflows
cmrln(w,c,u,r)	Non-large shares imported commodities by region	**Special sets for modules: Activation of the alternate intermediate input nest:**	
cml(c,u,r)	Commodities with large shares	*ui(u)*	Intermediate use
cx(c,r)	Commodities produced domestically	Subsets related to u:	
cxn(c,r)	Commodities NOT produced domestically AND imported	*uin(u)*	Final use categories
cd(c,u,r)	Commodities produced and demanded domestically	*ri(r)*	Activation of equation for alternate int. use nesting
cdn(c,u,r)	Commodities NOT produced and demanded domestically	*rin(r)*	Activation of equation without alternate int. use nesting
cintd(c,r)	Commodities with intermediate demand by region	**A macro SAM that facilitates checking various aspects of model calibration**	
cintdn(c,r)	Commodities without intermediate demand by region	*ss*	ASAM categories
cqq(c,u,r)	Commodities and uses and regions with CES fn at supply nest	**Finally various other sets are declared to facilitate model operation:**	
cqqn(c,u,r)	Com. and uses and regions with Leontief fn at supply nest	*sacn(sac)*	SAM accounts excluding TOTAL
cqs(c,u,r)	Commodities and uses and regions with CES fn at supply nest	*ssn(ss)*	ASAM categories excluding TOTALS
cqsn(c,u,r)	Com. and uses and regions with Leontief fn at supply nest	*fcons*	Set for parameters controlling program flow
		mcons	Set for parameters controlling model content

Source: Authors' compilation.

Table 3. List of mapping sets

The model also makes use of a series of mapping files that are used to link sets:			
map_w_tmr(w,tmr)	Ad valorem Tariff mapping	*map_w_r(w,r)*	Region to trade partner mapping
map_tmr_w(tmr,w)	Ad valorem Tariff mapping reverse	*map_wwu_r(wwu,r)*	Region to trade partner mapping by use
map_w_tmrs(w,tmrs)	Specific Tariff mapping	*map_f_tff(f,tff)*	Factor taxes to factors
map_tmrs_w(tmrs,w)	Specific Tariff mapping reverse	*map_tff_f(tff,f)*	Factor taxes to factors reverse
map_w_ter(w,ter)	Export tax mapping	*map_aagg_a(aagg,a)*	Mapping from activies to aggregate activities
map_ter_w(ter,w)	Export tax mapping reverse	*map_cagg_c(cagg,c)*	Mapping from commodities to aggregate commodities
map_c_w_marg_u (c,w,owatpmarg,u)	Trade margin mapping of owatpmarg to ct2 and w	*map_wagg_w (wagg,w)*	Mapping from regions to aggregate regions
map_marg_w (owatpmarg,w)	Trade margin mapping of w to owatpmarg	*map_ragg_r(ragg,r)*	Mapping from regions to aggregate regions
map_r_w(r,w)	Region to trade partner mapping	*map_fag_f(ff,f)*	Mapping from natural factors f to aggregates

Source: Authors' compilation.

Table 4. List of variables

ADFD(ff,a,r)	Shift parameter for factor and activity specific efficiency	*GLOBESLACK*	Slack variable for Globe
ADFDaADJ(a)	Activity Scaling Factor for flow parameter on ADFD	*HEXP(h,r)*	Household consumption expenditure
ADFDfADJ(f)	Factor Scaling Factor for flow parameter on ADFD	*HTAX(r)*	Household income tax revenue
ADFDrADJ(r)	Region Scaling Factor for flow parameter on ADFD	*IADJ(r)*	Investment scaling factor
ADVA(a,r)	Shift parameter for CES production functions for QVA	*INVEST(r)*	Total investment expenditure
ADVAADJ(r)	Scaling Factor for Shift parameter on CES functions for QVA	*INVESTSH(r)*	Value share of investment in total final dom demand
ADX(a,r)	Shift parameter for CES production functions for QX in r	*ITAX(r)*	Indirect tax revenue
ADXADJ(r)	Scaling Factor for Shift parameter on CES functions for QX	*KAPGOV(r)*	Government Savings
CPI(r)	Consumer price index - Region numeraires	*KAPREG(w,r)*	Bilateral current account balance
DADVA(r)	Partial scaling factor for Shift parameter on CES funct. for QVA	*KAPWOR(r)*	Current account balance
DADX(r)	Partial scaling factor for Shift parameter on CES funct. for QX	*KAPWORSYS*	Slack variable for global system
DREM(r)	Partial remittance rate scaling factor	*MSTAX(r)*	Specific Import tariff revenue
DSHH(r)	Partial household savings rate scaling factor	*MTAX(r)*	Ad valorem Import tariff revenue
DTE(r)	Uniform adjustment to Export taxes	*PCD(c,r)*	Consumer price of household consumtion
DTF(r)	Uniform adjustment to factor use tax by activity	*PD(c,u,r)*	Consumer price for domestic supply of commodity c
DTM(r)	Uniform adjustment to Ad valorem Tariff rates	*PE(c,u,r)*	Domestic price of exports by commodity c
DTMS(r)	Uniform adjustment to Specific Tariff rates	*PER(c,u,w,r)*	Domestic price of exports of comm'y to regions
DTS(r)	Uniform adjustment to sales tax	*PGD(c,r)*	Consumer price of government consumption
DTV(r)	Uniform Value added tax rate scaling factor	*PINT(a,r)*	Price of aggregate intermediate input
DTX(r)	Uniform adjustment to indirect tax	*PINTD(c,r)*	Consumer price of intermediate inputs
DTYF(r)	Uniform adjustment to direct tax on factors	*PINVD(c,r)*	Consumer price of investment demand
DTYH(r)	Uniform adjustment to direct tax on households	*PM(c,u,r)*	Domestic price of competitive imports of commodity c
EG(r)	Expenditure by government	*PML(c,u,r*	Dom. price of imports of c from region with small shares
ER(r)	Exchange rate (domestic per world unit)	*PMR(w,c,u,r)*	Dom. price of imports of comm'y c from regions
ERPI	Exchange rate index - Global numeraire	*PMS(c,u,r)*	Dom. price of imports of c from region with large shares
ETAX(r)	Export tax revenue	*PPI(r)*	Producer (domestic) price index - Region numeraires
FD(ff,a,r)	Demand for factor f by activity a in r	*PQD(c,u,r)*	Consumer price of composite commodity c
FS(ff,r)	Supply of factor f in r	*PQS(c,u,r)*	Supply price of composite commodity c
FTAX(r)	Factor use tax revenue	*PS(c,u,r)*	Producer price of composite domestic output by use
FYTAX(r)	Factor income tax revenue	*PT(c,u,r)*	Price of imported transport services (same price to imp. from r)
GDP(r)	Gross Domestic Product by Expenditure definition	*PVA(a,r)*	Value added price for activity a in r

Table 4. List of variables (continued)

PWE(c,u,w,r)	World price of exports of commodity c from region r in dollars	*STAX(r)*	Sales tax revenue
PWM(w,c,u,r)	CIF price of competitive imports of commodity c from region w	*TE(c,u,w,r)*	Export taxes on exported comm'y c from r to w
PWMFOB(w,c,u,r)	FOB price of competitive imports of commodity c from region w	*TEADJ(r)*	Export subsidy scaling factor
PX(a,r)	Composite price of output by activity a	*TF(ff,a,r)*	Tax rate on factor use
PXC(c,r)	Producer price of composite domestic output	*TFADJ(r)*	Factor use tax scaling factor
QCD(c,h,r)	Household consumption by commodity c	*TM(w,c,u,r)*	Ad valorem tariff rates on imported comm'y c from w by r
QD(c,u,r)	Domestic demand for commodity c	*TMADJ(r)*	Ad valorem tarrif rate scaling factor
QE(c,u,r	Domestic output exported by commodity c	*TMS(w,c,u,r)*	Specific tariff rates on imported comm'y c from w by r
QER(c,u,w,r)	Exports of comm'y c to regions and aggregates	*TMSADJ(r)*	Specific tarrif rate scaling factor
QGD(c,r)	Government consumption demand by commodity c	*TOTSAV(r)*	Total savings
QGDADJ(r)	Government consumption demand scaling factor	*TS(c,u,r)*	Sales tax rate
QINT(a,r)	Agg quantity of intermediates used by activity a in r	*TSADJ(r)*	Sales tax rate scaling factor
QINTD(c,r)	Demand for intermediate inputs by commodity in r	*TV(c,r)*	Value added tax rates
QINVD(c,r)	Investment demand by commodity c	*TVADJ(r)*	Value added tax rate scaling factor
QM(c,u,r)	Imports of commodity c	*TX(a,r)*	Indirect tax rate
QML(c,u,r)	Supply of composite import from large share regions	*TXADJ(r)*	Indirect tax scaling factor
QMR(w,c,u,r)	Imports of comm'y c from regions and aggregates	*TYF(f,r)*	Direct tax rate on factor income
QMS(c,u,r)	Supply of composite import from large share regions	*TYFADJ(r)*	Factor income tax scaling factor
QQ(c,u,r)	Supply of composite commodity c	*TYH(h,r)*	Direct tax rate on households
QS(c,u,r)	Domestic production by commodity c in r by use	*TYHADJ(r)*	Income tax scaling factor
QT(w,c,u,r)	Quantity of margin services for total imports from region w	*UNEMP(f,r)*	Unemployed factors
QVA(a,r)	Quantity of aggregate value added for level 1 production	*VFDOMD(r)*	Value of final domestic demand
QX(a,r)	Domestic production by activity a in r	*VGDSH(r)*	Value share of govt consumption in total final dom demand
QXC(c,r)	Domestic production by commodity c in r	*VTAX(r)*	Value added tax revenue
REMADJ(r)	Remittance rate scaling factor	*WALRAS(r)*	Slack variable for Walras's law
REMIN(h,w,r)	Remittances in	*WF(ff,r)*	Price of factor f in r
REMINW(h,w,r)	Remittances in at world currency	*WFDIST(ff,a,r)*	Sectoral proportion for factor prices in r
REMOUT(w,h,r)	Remittances out	*YF(f,r)*	Income to factor f
REMOUTW(w,h,r)	Remittances out at world currency	YFDIST(f,r)	Factor income for distribution after depreciation
REMRYHF(w,h,r)	Remittances out rate	*YG(r)*	Government income
SADJ(r)	Savings rate scaling factor	YH(h,r)	Income to household h
SHH(h,r)	Household savings		

Source: Authors' compilation.

Table 5. List of model parameters

ac(c,r)	Shift parameter for Armington CES function	*dadfd(f,a,r)*	Change in shift par. for factor and activity specific efficiency
acr(c,r)	Shift par. for Armington CES over imports by aggregate region	*delta(c,r)*	Share parameter for Armington CES function
actusesh(c,u,r)	Distribution of production over uses	*deltafd(ff,ff,a,r)*	CES Share parameters for aggregated FD fag using ff by a
adfag(ff,a,r)	Shift parameter for factor and activity specific efficiency	*deltar(w,c,r)*	Share par. for Armington CES over imp. by region & aggregate
adfdb(f,a,r)	Base Shift parameter for factor and activity specific efficiency	*deltava(f,a,r)*	Share parameters for CES production functions for QVA
adva01(a,r)	0-1 par for flexing of shift parameter on functions for QVA	*deltax(a,r)*	Share parameter for CES production functions for QX in r
advaadj01(a,r)	0-1 par for flexing the multiplicative scaling for QVA	*deprec(f,r)*	depreciation rate by factor f on stock of factor f
advab(a,r)	Shift parameter for CES production functions for QVA	*frisch(h,r)*	Elasticity of the marginal utility of income
adx01(a,r)	0-1 par for flexing of shift parameter on functions for QX	*gamma(c,r)*	Share parameter for CET function
adxadj01(a,r)	0-1 par for flexing the multiplicative scaling for QX	*gammar(c,w,r)*	Share parameter for CET over exports by region & aggregate
adxb(a,r)	Shift parameter for CES production functions for QX in r	*hexps(h,r)*	Subsistence consumption expenditure
at(c,r)	Shift parameter for CET function	*hvash(h,f,r)*	Share of income from factor f to household h
atr(c,r)	Shift param for CET over exports by aggregate region	*ioqdqq(c,u,r)*	Share of QD in QQ
beta(c,h,r)	Marginal budget shares	*ioqdqs(c,u,r)*	Share of QD in QS
comhav(c,h,r)	Household consumption shares	*ioqeqs(c,u,r)*	Share of QE in QS
dabadva(a,r)	Change in base shift parameter on functions for QVA	*ioqint(c,a,r)*	Intermediate input output coefficients
dabadx(a,r)	Change in base shift parameter on functions for QX	*ioqintqx(a,r)*	Agg intermed quantity per unit QX for level 1 Leontief agg
dabrrh(w,h,r)	Change in base household remittance rates	*ioqmlqm(c,u,r)*	Share of QML in QM
dabshh(h,r)	Change in base household saving rates	*ioqmqq(c,u,r)*	Share of QM in QQ
dabte(c,w,r)	Change in base export tax on comm'y imported from region w	*ioqmrqms(w,c,u,r)*	Share of QMR in QMS
dabtf(f,a,r)	Change in base factor us tax rate on activities	*ioqmsqm(c,u,r)*	Share of QMS in QM
dabtm(w,c,r)	Change in base tariff rates on comm'y imptd from region w	*ioqvaqx(a,r)*	Agg value added quant per unit QX for level 1 Leontief agg
dabtms(w,c,u,r)	Change in base specific tariffs on comm'y imptd by regn	*ioqx(c,a,r)*	Use matrix coefficients
dabts(c,r)	Change in base sales tax rate	*ioqxcqx(a,c,r)*	Share of commodity c in output by activity a
dabtv(c,r)	Change in base value added tax rate	*margcor(w,c,cp,r)*	Margin c per unit of r's import of commodity cp from region w
dabtx(a,r)	Change in base indirect tax rate	*mod_elaste(c,u,r)*	Level 1 CET elasticities used in the model
dabtyf(f,r)	Change in base direct tax rate on factors	*mod_elastm(c,u,r)*	Level 1 CES elasticities used in the model
dabtyh(h,r)	Change in base direct tax rate on households	*mod_elastre(c,u,r)*	Level 2 CET elasticities used in the model

Table 5. List of model parameters (continued)

mod_elastrm(c,u,r)	Level 2 CES elasticities used in the model	*thetava(f,a,r)*	Share of primary factor in QVA
mod_elastva(a,r)	Level 2 CES elasticities used in the model	*thetax(a,r)*	Share of QVA in QX
mod_elastx(a,r)	Level 1 CES elasticities used in the model	*tm01(w,c,r)*	0-1 par for potential flexing of tariff rates on comm'ies
qcdconst(c,h,r)	Volume of subsistence consumption	*tmb(w,c,r)*	Base tariff rates on comm'y imported from region w
qgdconst(c,r)	Government demand volume	*tmreal(w,c,r)*	Real tariff rates by commodity and region
qgdconst0(c,r)	Initial Government demand volume	*tms01(w,c,u,r)*	0-1 par for flexing of specific tariff rates on comm'ies
qinvdconst(c,r)	Investment demand volume	*tmsb(w,c,u,r)*	Specific tariff rates on comm'y imported from region w
remrYHF0(w,h,r)	Initial remittance rate	*ts01(c,r)*	0-1 par for potential flexing of sales tax rates
remrYHF01(w,h,r)	0-1 par for potential flexing of remittance rates	*tsb(c,r)*	Base sales tax rate
rhoc(c,r)	Elasticity parameter for Armington CES function	*tv01(c,r)*	0-1 par for flexing of value added tax rates
rhoe(c,r)	Elast parameter for CET over exports by aggregate region	*tv02(c,u,r)*	VAT rates for initialisation
rhofd(ff,a,r)	Elasticity parameter for CES prodn fns for aggregated FD	*tvb(c,r)*	Base value added tax rates
rhom(c,r)	Elast par. for Armington CES over imports by aggregate region	*tx01(a,r)*	0-1 par for potential flexing of indirect tax rates
rhot(c,r)	Elasticity parameter for autput CET function	*txb(a,r)*	Base indirect tax rate on activity a
rhova(a,r)	Elasticity parameter for CES production function for QVA	*tyf01(f,r)*	0-1 par for potential flexing of direct tax rates on factors
rhox(a,r)	Elasticity parameter for CES production function for QX in r	*tyfb(f,r)*	Base factor income tax rate
shh01(h,r)	0-1 par for potential flexing of household saving rates	*tyh01(h,r)*	0-1 par for potential flexing of direct tax rates on h'holds
shhb(h,r)	Base household saving rates	*tyhb(h,r)*	Base direct tax rate on household h
sumelast(h,r)	Weighted sum of income elasticities	*unemp_rate(f,r)*	Unemployment rates
te01(c,w,r)	0-1 par for potential flexing of export taxes on comm'ies	*use(c,a,r)*	Use matrix transactions
teb(c,w,r)	Base export tax rates on exports of comm'y c to region w	*vqcdsh(c,r)*	Share of commodity c in total household commodity demand
tf01(f,a,r)	0-1 par for potential flexing of factor use tax rates	*vqdsh(c,u,r)*	Share of value of domestic output for the domestic market
tf02(ff,a,r)	tf for calibration of production functions	vqesh(ref)	Share of total exports by reference regions
tfb(f,a,r)	Base factor use tax rate	yhelast(c,h,r)	(Normalised) household income elasticities

Source: Authors' compilation.

Table 6. List of parameters for model data and calibration checks

Parameters for model data			
ELASTE(c,r)	Elasticities for CET functions	*FACTUSE(f,a,r)*	Factor use by activity
ELASTF(r,h)	Frisch parameters for LES demand system	*flow_cont(fcons)*	Values for parameters controlling program flow
ELASTFD(ff,a,r)	Elasticities for CES production funct. level 3	*impmarg(w,c,cp,u,r)*	Margins of type c paid by cp on r's imports from w
ELASTM(c,r)	Elasticities for Armington CES functions	*imprtsh(w,c,u,r)*	Import trade shares
ELASTMG(c,r)	Elasticities for Armington CES functions	*mod_cont(mcon)s*	Values for parameters controlling model content
ELASTRE(c,r)	Elasticities for CET over regions level 3	*popn(r)*	GTAP population data
ELASTRM(c,r)	Elast. for Armington CES over regions Level 3	*SAMDOM(sac,sacp,sacpp,r)*	Domestic matrix by use
ELASTRMG(c,r)	Elasticities for Armington CES over regions	*SAMG(sac,sacp,r)*	The GTAP SAM database
ELASTVA(a,r)	Elasticities for CES production function level 2	*SAMIMP(sac,sacp,sacpp,r)*	Import matrix by use
ELASTVAG(a,r)	Elasticities for CES production function level 2	*samscal*	SAM scaling factor
ELASTX(a,r)	Elasticities for CES production function level 1	*un_rate(r,f)*	Unemployment rates
ELASTY(c,h,r)	Income elast. of demand for LES demand system		
Parameters for calibration checks			
ASAMG1(sac,sacp,r)	Post calibration global macro SAM	*deltaxCHK(r)*	Check on share par. for CES prod. functions for QX
ASAMG2(sac,sacp,r)	Post solve global macro SAM	*DIFFSAMG1(sac,sacp,r)*	Differences between SAMG and SAMG1
CHKSAMG1(sac,r)	Check on row and column totals	*DIFFSAMG2(sac,sacp,r)*	Differences between SAMG and SAMG1
CNTSAMG1(r)	Count of non zero entries in DIFFSAMG1	*gammarchk(c,u,r)*	Check on gammar
CNTSAMG2(r)	Count of non zero entries in DIFFSAMG1	*HCON(c,r)*	Check on household consumption
COMTAXE0(r)	Check on export taxes	*ioqmCHK(c,u,r)*	Check on ioqm
COMTAXM0(r)	Check on import tariffs	*ioqmrqmsCHK(c,u,r)*	Check on ioqmrqm
COMTAXS0(r)	Check on sales taxes	*ioqqCHK(c,u,r)*	Check on ioqq
COMTAXT0(r)	Check on total commodity taxes	*numerchk*	Numeraire check value
deltafdchk(ff,a,r)	Check on deltafd	*perDIFFSAMG1(sac,sacp,r)*	Percentage differences btw SAMG and SAMG1
deltarCHK(c,u,r)	Check on deltar	*perDIFFSAMG2(sac,sacp,r)*	Percentage differences btw SAMG and SAMG1
deltavacheck(a,r)	Check on deltava	*QECALIB(c,u,r)*	Check on calibrated value of QE0

Table 6. List of parameters for model data and calibration checks (continued)

ASAMG1(sac,sacp,r)	Post calibration global macro SAM	*deltaxCHK(r)*	Check on share par. for CES prod. functions for QX
QEDIFF(c,u,r)	Difference between calibrated and actual QE0	*QT_chk(w,c,u,r)*	Check on QTL v QT0
QER_chk(c,u,w,r)	Check on QER	*QT0sum(c,u,r)*	Sum by w of QT0
QM02(c,u,r)	Alternate calculation	*QTsum(c,u,r)*	Sum by w of QT
QM02chk(c,u,r)	Check on QM0	*SAMG1(sac,sacp,r)*	Post calibration global SAM
QM03(c,u,r)	Alternate calculation	*SAMG12CHK(sac,sacp,r)*	Check on comparision of SAMG1 with SAMG2
qm03chk(c,u,r)	Check on QM0	*SAMG12CHK_alt(sac,sacp,r)*	Check on comparision of SAMG1 with SAMG2
QMCALIB(c,u,r)	Check on calibrated value of QM0	*SAMG2(sac,sacp,r)*	Post solve global SAM
QMDIFF(c,u,r)	Difference between calibrated and actual QM0	*SAMG2CHK(sac,r)*	Check on row and column totals
qqcalib(c,u,r)	Check on QQ0	*TOTCON(r)*	Check on total consumption
qqdif(c,u,r)	Check on QQ0		

Source: Authors' compilation.

Table 7. Module parameters and variables

Parameter		***Variable***	
	Local Content Requirement (LCR)		
lcrsh(c,u,r)	Local content requirement share	*QDLCR(c,u,r)*	Additional domestic produced quantity provided under LCR
		QDNL(c,u,r)	Domestic produced quantity not affected by LCR
		QLCR(c,u,r)	Local content requirement quantity
		QQARM(c,u,r)	Supply of composite commodity (Armington function)
		SLACK(c,u,r)	Slack variable QDL
	Alternate intermediate input nesting		
ac_a(c,u,a,r)	Shift parameter for Armington CES function by activity	*PDA(c,u,a,r)*	Activity specific price for domestic supply of commodity c
delta_a(c,u,a,r)	Share parameter for Armington CES function by activity	*PINTA(c,a,r)*	Activity specific price of aggregate intermediate input
ioqdaqq(c,u,a,r)	Share of domestic supply in composite intermediate supply by activity	*PINTS(c,u,a,r)*	Activity specific supply price of composite commodity c
ioqmaqq(c,u,a,r)	Share of imp. in composite intermediate supply by a	*PMA(c,u,a,r)*	Activity specific domestic price of competitive imports of comm'y c
tsa(c,u,a,r)	Sales tax parameter for intermediates by activity	*QDA(c,u,a,r)*	Activity specific domestic demand for commodity c
		QINTA(c,a,r)	Aggregate quantity of intermediates used by activity a in r
		QMA(c,u,a,r)	Activity specific imports of commodity c
	LCR - Alternate intermediate input nesting		
lcrsh_A(c,u,a,r)	Activity specific local content requirement share	*QDLCR_A(c,u,a,r)*	Activity specific additional domestic produced quantity provided under LCR
		QDNL_A(c,u,a,r)	Activity specific domestic produced quantity not affected by LCR
		QLCR_A(c,u,a,r)	Activity specific local content requirement quantity
		QQARM_A(c,u,a,r)	Activity specific supply of composite commodity (Armington function)
		SLACK_A(c,u,a,r)	Activity specific slack variable QDL
	Price preference instrument		
tsd(c,u,a,r)	Sales tax parameter for domestic intermediates by activity	*PDA2(c,u,a,r)*	Activity specific consumer price for domestic supply
tsm(c,u,a,r)	Sales tax parameter for imported intermediates by activity	*PMA2(c,u,a,r)*	Activity specific domestic consumer price of imports

Source: Authors' compilation.

1.3.3 Commodity market structure by use category[8]

Use categories

25. Commodities are distinguished by use category (u) into commodities designed for intermediate use, use by households, government consumption and investment commodities. Figure 2 shows the structure of the commodity market. Domestic production ($QXC_{c,r}$) of commodity c in region r supplies the 4 use categories ($QS_{c,u,r}$), assuming perfect substitutability (Equation C1 below), displayed at the bottom of Figure 2. Hence, the production of a commodity in a specific use category is determined by its demand while the initial prices of production (i.e., production costs) are equal amongst use categories ($PS_{c,u,r}$, Eq. C2 below).

26. The Globe region has a special role in the model as it is a constructed region that serves as global bank to distribute trade margins. The Globe region is described in detail in section 1.3.6. The right column of the equation tables indicate if equations apply to the Globe region or not.

	Name	Equation	Number of Eq. and Var.	Variable	Globe Region
		Commodity by use block			
(C1)	$COMOUT2_{c,r}$	$QXC_{c,r} = \sum_u QS_{c,u,r}$	(c*rgn)	$QXC_{c,r}$	No
(C2)	$PXCDEF_{c,u,r}$	$PXC_{c,r} = PS_{c,u,r}$	(c*u*rgn)	$PS_{c,u,r}$	No

Exports

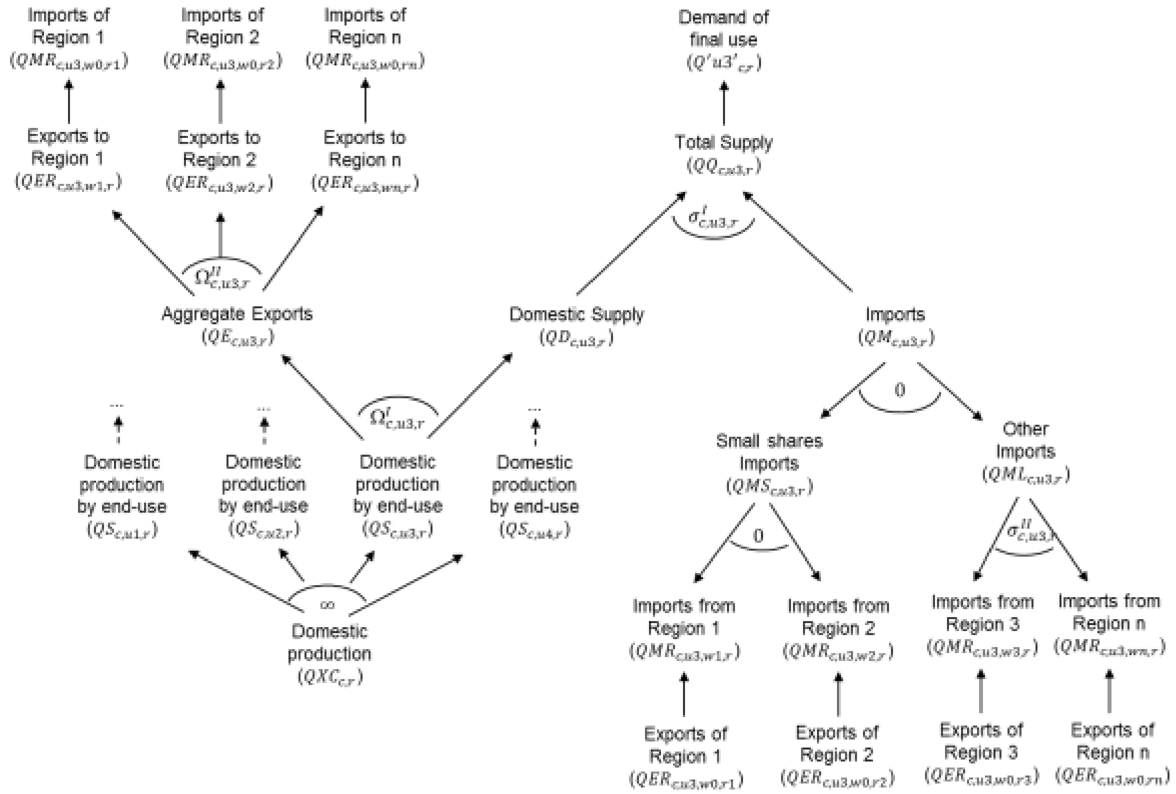
27. Export commodities are generally treated as imperfect substitutes, with the exception of exports from the Globe region (of trade and transport services) that are homogeneous. This makes the treatment of exports a little bit complicated. The presumption of imperfect substitution is the default presumption in this model; reasons for this decision being its symmetry with the Armington assumption on the imports side, the amelioration of the terms of trade effects associated with the Armington assumption and a belief that in general there is differentiation between domestic and export markets. However, there are proponents of the arguments for treating exports as perfect substitutes and there are clearly cases where such an assumption may be appropriate, e.g., supplies of unprocessed mineral products.[9] Imperfect substitution is introduced with a two level Constant Elasticity of Transformation (CET) formulation which allows firms to differentiate prices on the domestic and export markets, depending on markets shares and price elasticities ($\Omega^{I}_{c,u,r}$). On the first stage of the CET nest, commodity supply is distributed between the domestic market and the aggregated export market (Figure 2), while on the second stage the aggregate export supply is distributed among the different export destination regions. The responsiveness to relative price changes on the second stage is governed by the export elasticity ($\Omega^{II}_{c,u,r}$), which is commodity, use category and region specific and is based on the import elasticities. This structure gives also the possibility to depict global value chain characteristics. The distribution decision on both levels is based on relative prices: aggregate export supply is, on the first stage, determined by the relative price for the commodity on the domestic market and export market. The price of composite exports is determined by the export prices to different

8 This section is mainly based and partly identical to McDonald et al. (2013).

9 The GTAP model assumes perfect substitution and historically it has been argued that perfect substitution is appropriate for Australia.

regions which also determine the allocation of exports at the second stage. A formulation of the model allows the CET functions to be switched off at either or both levels of the export supply nest for specific commodities and/or for specific regions.

Figure 2. Structure of commodity market by use category structure



Source: Authors' compilation.

28. Price relationships are depicted in Figure 3. The domestic prices of commodity *c* exports by use category *u* destination *w* and source region *r* ($PER_{c,u,w,r}$) are defined as the product of world prices of exports ($PWE_{c,u,w,r}$) – also defined by commodity, use category, destination and source region – the source region's exchange rate (ER_r) and one minus the export tax rate ($TE_{c,u,w,r}$) (Eq. X2 below). Commodities can be non-traded, thus the equations for the domestic prices of exports (and imports) are only implemented for those commodities that are traded; this requires the use of a dynamic set *cer* which is defined by those commodities that are exported in the base data. Also notice that the world prices of exports ($PWE_{c,u,w,r}$) are defined as variables; in a global model the small country trade assumption is not valid since, by definition, world prices are endogenous and therefore all regions are treated as 'large' producers of a commodity.

29. The prices of the composite export commodities can then be expressed as simple volume weighted averages of the of the export prices by region, where and the price ($PE_{c,u,r}$) and quantity ($QE_{c,u,r}$) of the composite export commodity c of use category u from region r, and the weights are the volume shares of exports and are variable. This comes from the fact that a CET function is linear homogenous and hence Eulers theorem can be applied. Notice however that equation X1 is only implemented of the set *rgn*, i.e., the region Globe is excluded. The composite export price for trade margin commodities from Globe is defined in equation X3, assuming that trade margin commodities exported by Globe are perfect substitutes for each other, i.e., the same price is paid for each trade margin commodity by all purchasing regions.

	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Exports block			
(X1)	$PEDEF_{c,u,r}$	$PE_{c,u,r} = \frac{\sum_w \left(PER_{c,u,w,r} * QER_{c,u,w,r}\right)}{QE_{c,u,r}}$	(ce*u*rgn)	$PE_{c,u,r}$	No
(X2)	$PERDEF_{c,u,w,r}$	$PER_{c,u,w,r} = PWE_{c,u,w,r} * \left(1 - TE_{c,u,w,r}\right) * ER_r$	(cer*u*w *rgn)	$PER_{c,u,w,r}$	No
(X3)	$PERDEFHG_{c,u,w,r}$	$PER_{c,u,w,r} = PE_{c,u,r}$	(ct2*u*w*1)		Yes
(X4)	$CET_{c,u,r}$	$QS_{c,u,r} = at_{c,u,r}\left(gamma_{c,u,r} * QE_{c,u,r}^{rhot_{c,u,r}} + \left(1 - gamma_{c,u,r}\right)QD_{c,u,r}^{rhot_{c,u,r}}\right)^{\left(\frac{1}{rhot_{c,u,r}}\right)}$	(c*u*rgn)	$QD_{c,u,r}$	No
(X5)	$ESUPPLY_{c,u,r}$	$QE_{c,u,r} = QD_{c,u,r} * \left(\frac{PE_{c,u,r}}{PD_{c,u,r}} * \frac{\left(1 - gamma_{c,u,r}\right)}{gamma_{c,u,r}}\right)^{\left(\frac{1}{rhot_{c,u,r}-1}\right)}$	(c*u*rgn)	$QE_{c,u,r}$	No
(X6)	$CETALT_{c,u,r}$	$QS_{c,u,r} = QD_{c,u,r} + QE_{c,u,r}$	((cd ∩ cen) or (cdn ∩ ce) * u * rgn)		No
(X7)	$QEDEF_{c,u,r}$	$QE_{c,u,r} = ioqeqs_{c,u,r} * QS_{c,u,r}$	(cqsn*u*rgn)	$QE_{c,u,r}$	No
(X8)	$QDDEF_{c,u,r}$	$QD_{c,u,r} = ioqdqs_{c,u,r} * QS_{c,u,r}$	(cqsn*u*rgn)	$QD_{c,u,r}$	No
(X9)	$CETLEV2_{c,u,w,r}$	$QER_{c,u,w,r} = QE_{c,u,r} * \left(\frac{PER_{c,u,w,r}}{PE_{c,u,r} * gammar_{c,u,w,r} * atr_{c,u,r}^{rhoe_{c,u,r}}}\right)^{\left(\frac{1}{rhoe_{c,u,r}-1}\right)}$	(cer*w*rgn)	$QER_{c,u,w,r}$	No
(X10)	$TSHIP_{c,u,r}$	$QE_{c,u,r} = QM_{c,u,r}$	(ct2*1)	$QE_{c,u,r}$	Yes
(X11)	$CETREQG_{c,u,r}$	$QE_{c,u,r} = \sum_w QER_{c,u,w,r}$	(ct2*1)	$QE_{c,u,r}$	Yes

30. Domestic commodity outputs ($QS_{c,u,r}$) are either exported as composite commodities ($QE_{c,u,r}$) or supplied to the domestic market ($QD_{c,u,r}$). The allocation of output between the domestic and export markets is determined by the output transformation functions, CET functions, (Eq. X4) with the optimum combinations of $QE_{c,u,r}$ and $QD_{c,u,r}$ determined by first-order conditions (Eq. X5). In this version of the model primal forms of the CET is used with associated first-order conditions. However, some commodities are non-traded and therefore equations X4 and X5 are implemented if and only if the commodity is traded. This does not define domestic commodity outputs for non-traded commodities, where by definition the quantity supplied to the domestic market is the amount produced. It is also necessary to cover the possibility that a commodity may be produced domestically and exported but not consumed domestically. These two sets of possibilities are covered by equation X6. Equations X7 and X8 allow for the possibility of small export shares[10], for small shares there is the possibility to assume supplies in fixed shares to avoid eventual large terms of trade effects.

10 The definition of 'small', and hence by complement 'large', is selected by the user when calibrating the model. The same applies for imports.

31. These quantity equations deal however only with the composite export commodities, i.e., hypothetical commodities whose roles in the model are to act as neutral intermediaries that enter into the first-order conditions that determine the optimal mix between domestic use and exports of domestic commodity production (Eq. X5). In the model the composite export commodities are themselves CET aggregates of commodity exports to different regions ($QER_{c,u,w,r}$), and the appropriate first order condition is given by equation X9[11]. Note however that equation X9 does not define the exports of trade margin commodities by Globe; this is because these commodities are assumed to be perfect substitutes and therefore simple addition is adequate, this is done by equation X11.

32. Finally there is a need for an equilibrium condition for trade by Globe. Since Globe is an artificial construct whose sole role in the model is to distribute margins, it must always balance its trade within each period. Thus the volume of exports of trade margin commodities by Globe must be exactly equal to the volume imports of trade margin commodities (Eq. X10).

Imports

33. Domestic demand is served from domestic supply and import supply ($QM_{c,u,r}$). Import supply is modelled as three-stage CES function assuming imperfect substitutability between domestically produced commodities and imported commodities, displayed on the bottom right of in Figure 2. The composition of domestic and imported commodities is determined on the first stage by the relative price for the domestic commodity and aggregate import commodity. The second stage allows for a special treatment of imports from countries with small volumes ($QMS_{c,u,r}$) and as a consequence are exposed to large relative price effects. The definition of a small import share can be freely chosen and by default import shares of less than 0.1% are considered small. On the second stage import commodities are aggregated in fixed shares from aggregate imports with small trade volumes and aggregate other imports ($QML_{c,u,r}$), i.e. from sources with import shares greater than 0.1%. Aggregate other imports is a CES-composite of imports from different regions ($QMR_{c,u,w,r}$) which are not considered small and are responsive to relative prices. At the third stage regions that contribute small volume shares of imports form an aggregate. The shares of that aggregate are fixed. This basic structure is applied for each use-market.

34. The prices of imported commodities are made up of several components (Figure 3). The export price in foreign currency units – valued free on board (fob) ($PWMFOB_{w,c,u,r}$) – plus the cost of trade and transport services, which gives the import price carriage insurance and freight (cif) paid ($PWM_{w,c,u,r}$), plus any import duties; all of which are then converted into domestic currency units ($PMR_{w,c,u,r}$). Clearly the import price value fob ($PWMFOB_{w,c,u,r}$) is identical to the export price valued fob ($PWE_{c,u,w,r}$) – this condition is imposed in the market clearing block (see below) – and hence the cif price is defined in equation M3, where $margcor_{w,cp,c,u,r}$ is the quantity of trade and transport services required to import a unit of the imported commodity and $PT_{c,u,r}$ is the price of trade and transport services. Embedded in the definition of the coefficient $margcor_{w,cp,c,u,r}$ is the explicit assumption that transporting a commodity from a specific source to a specific destination requires the use of a specific quantity of services (Eq. M15) – the actual cost of these services can vary according to changes in the prices of the trade and transport services or the quantity of services required to transport a particular commodity.

35. The domestic prices of imports from a region ($PMR_{w,c,u,r}$) (Eq. M4) are then defined as the product of world prices of imports ($PWM_{w,c,u,r}$) – after payment for carriage, insurance and freight (cif) – the exchange rate (ER_r) and one plus the import tariff rate ($TM_{w,c,u,r}$). The possibility of non-traded commodities means that the equations for the domestic prices of imports are only implemented for those commodities that are

[11] Initially the formulation of X9 is not intuitive but, as demonstrated by McDonald and Thierfelder (2013, Appendix A1), the formulation is a straightforward manipulation of a more conventional representation; this form is used because it improves model performance.

traded; this requires the use of a dynamic set *cmr* which is defined by those commodities that are imported by a region from another region in the base data.

Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
	Imports block I Prices			
(M1) $PMLDEF_{c,u,r}$	$PML_{c,u,r} = \frac{\sum_w (PMR_{w,c,u,r} * QMR_{w,c,u,r})}{QML_{c,u,r}}$	(cml*u*r)	$PML_{c,u,r}$	Yes
(M2) $PMSDEF_{c,u,r}$	$PMS_{c,u,r} = \sum_w (ioqmrqms_{w,c,u,r} * PMR_{w,c,u,r})$	(cms*u*r)	$PMS_{c,u,r}$	Yes
(M3) $PWMDEF_{w,c,u,r}$	$PWM_{w,c,u,r} = PWMFOB_{w,c,u,r} + \sum_{cp} (margcor_{w,cp,c,u,r} * PT_{cp,u,r})$	(w*cmr*u*r)	$PWM_{w,c,u,r}$	Yes
(M4) $PMRDEF_{w,c,u,r}$	$PMR_{w,c,u,r} = (PWM_{w,c,u,r} * (1 + TM_{w,c,u,r}) + TMS_{w,c,u,r}) * ER_r$	(w*cmr*u*r)	$PMR_{w,c,u,r}$	Yes
(M5) $PMDEF_{c,u,r}$	$PM_{c,u,r} * QM_{c,u,r} = PML_{c,u,r} * QML_{c,u,r} + PMS_{c,u,r} * QMS_{c,u,r}$	(cm*u*r)	$PM_{c,u,r}$	Yes
(M6) $COSTMIN_{c,u,r}$	$QM_{c,u,r} = QD_{c,u,r} * \left(\frac{PD_{c,u,r}}{PM_{c,u,r}} * \frac{delta_{c,u,r}}{(1 - delta_{c,u,r})}\right)^{\left(\frac{1}{1+rhoc_{c,u,r}}\right)}$	(c,u,rgn)	$PD_{c,u,r}$	No

36. The model treats imports that account for 'small' shares of imports of a commodity by a region differently from those that account for 'large' shares of imports of a commodity by a region. This is because the operations of CES functions depend not only on the elasticity of substitution but also on the shares of arguments: commodities with 'small' trade shares can have a disproportionately large impact on the terms of trade in such aggregation functions. For commodities with 'small' trade shares it is assumed that they account for fixed proportions ($ioqmrqms_{w,c,u,r}$) of the total volume of imports of a commodity. The justification for this assumption rest upon a (vaguely defined) specific factor specification. The composite price of 'small' share imports ($PMS_{c,u,r}$) is therefore a quantity share weighted aggregate of the landed prices (Eq. M2). The composite price of 'large' share imports ($PML_{c,u,r}$) is a simple volume weighted averages of the import prices by region. This derives from the fact that a CES function is liner homogenous and hence Eulers theorem can be applied (Eq. M1).

37. The prices of the composite import commodities can also be expressed as a simple volume weighted averages of the import prices by region (Eq. M5) where $PM_{c,u,r}$ and $QM_{c,u,r}$ are the price and quantity of the composite import commodity *c* by region *r*, and the weights are the volume shares of imports and are variable. Notice however that (Eq. M5) is only controlled by the set *cm*, in contrast to (Eq. X1) – the composite export price – which was also controlled by the set *rgn*, i.e., the region Globe was excluded. This reflects the fact that the region Globe does import commodities using the same trading assumption as other regions but only exports homogenous trade and transport services, which explains the need for the equation X3.

	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Imports block II Quantities			
(M7)	$ARMINGTON_{c,u,r}$	$QQ_{c,u,r} = ac_{c,u,r} * \left(delta_{c,u,r} * QM_{c,u,r}^{-rhoc_{c,u,r}} + (1 - delta_{c,u,r}) * QD_{c,u,r}^{-rhoc_{c,u,r}}\right)^{\left(\frac{-1}{rhoc_{c,u,r}}\right)}$	(c*u*rgn)	$QM_{c,u,r}$	No
(M8)	$QMDEF_{c,u,r}$	$QM_{c,u,r} = ioqmqq_{c,u,r} * QQ_{c,u,r}$	(cqqn*u*rgn)	$QM_{c,u,r}$	No
(M9)	$ARMALT_{c,u,r}$	$QQ_{c,u,r} = QD_{c,u,r} + QM_{c,u,r}$	$(cx \cap cmn)$ or $(cxn \cap cm) * u * rgn)$		No
(M10)	$QMSEQ_{c,u,r}$	$QMS_{c,u,r} = ioqmsqm_{c,u,r} * QM_{c,u,r}$	(cms*u*r)	$QMS_{c,u,r}$	Yes
(M11)	$QMLEQ_{c,u,r}$	$QML_{c,u,r} = ioqmlqm_{c,u,r} * QM_{c,u,r}$	(cml*u*r)	$QML_{c,u,r}$	Yes
(M12)	$QMREQ_{w,c,u,r}$	$QMR_{w,c,u,r} = ioqmrqms_{w,c,u,r} * QMS_{c,u,r}$	(cmrs*u*r)	$QMR_{w,c,u,r}$	Yes
(M13)	$ARMLEV2_{w,c,u,r}$	$QMR_{w,c,u,r} = QML_{c,u,r}\left(\frac{PMR_{w,c,u,r} * acr_{c,u,r}^{rhom_{c,u,r}}}{PML_{c,u,r} * deltar_{w,c,u,r}}\right)^{\left(\frac{-1}{rhom_{c,u,r}+1}\right)}$	(w*cmrl*u*r)	$QMR_{w,c,u,r}$	Yes
(M14)	$QTEQ_{w,c,u,r}$	$QT_{w,c,u,r} = \sum_{cp}(QMR_{w,cp,u,r} * margcor_{w,c,cp,u,r})$	(w*ct2*u*rgn)	$QT_{w,c,u,r}$	No

38. The composite supply of the imported commodity ($QM_{c,u,r}$) is a Leontief aggregate of imports with 'small' ($QMS_{c,u,r}$) and 'large' ($QML_{c,u,r}$) shares using appropriately defined input-output coefficients (Eqs. M10 and M11). Similarly the quantities imported of the 'small' share commodities by source region are defined by fixed (input-output) coefficients (Eq. M12). The use of a two stage Leontief nest in this case ensures no substitution possibilities between the aggregate imports $QML_{c,u,r}$ and $QMS_{c,u,r}$; if some substitution possibilities are required the nesting system used for production can be adapted.

39. The composite imports of commodities with 'large' shares are defined as CES aggregates of the imports from different regions ($QMR_{w,c,u,r}$) (Eq. M13). The first order conditions come from the price definition terms for composite imports ($PML_{c,u,r}$) (Eq. M1) and are only implemented for those cases where there were import transactions in the base period – this is controlled by the set *cmr*. Like equation X9, the formulation of equation M13 is initially not intuitive but a straightforward manipulation of a more conventional representation; this form, which is effectively a set of first-order conditions, is used because it reduces the number of equations in the model.

40. The composite (consumption) commodities are then a mixture of composite imports ($QM_{c,u,r}$) and domestic demand from domestic production ($QD_{c,u,r}$). The mixtures between the domestic and import supplies are determined by the substitution functions, Constant Elasticity of Substitution (CES) functions (Eq. M7) with the optimal combinations of $QM_{c,u,r}$ and $QD_{c,u,r}$ being determined by first-order conditions (Eq. M6). Some commodities are non-traded and therefore equations M6 and M7 are implemented only if the commodity is traded, which leaves $QQ_{c,u,r}$ undefined for non-traded commodities. By definition, if there are no imports the quantity demanded by the domestic market is the amount produced, and if there is no domestic production the amount demanded is the amount imported. These two sets of possibilities are both covered by equation M9.

41. To address small aggregate import shares in a detailed database, aggregate imports and domestic supply can be set to form composite supply in fixed shares (Eq. M8). Just as with the other small shares features the definition of small shares can be freely chosen and is set by the user.

Prices

42. An overview over the relations between prices gives Figure 3. The model contains the assumption of the law of one price, since it is SAM based, thus prices are equal across rows of the SAM. An exception from this rule is made for exports, because the commodity c and use specific export price ($PE_{c,u,r}$) does not need to equal the purchaser price ($PD_{c,u,r}$). However, exports get a separate price variable in the model and are thus implicitly separate from domestically consumed goods. Similarly, the use categories introduce a new dimension to the standard SAM and the law of one price is theoretically maintained. For practical reasons, however, the SAM is stored in a more condensed format, making the interpretation of prices more complicated.

43. The composite price equations (Eqs. CP1-CP6) are derived from the first order conditions for tangencies to consumption and production possibility frontiers. By exploiting Euler's theorem for linearly homogeneous functions the composite prices can be expressed as expenditure identities rather than dual price equations for export transformation and import aggregation, such that $PQS_{c,u,r}$ is the weighted average of the producer price of a commodity, when $PD_{c,u,r}$ is the producer price of domestically produced commodities and $PM_{c,u,r}$ the domestic price of the composite imported commodity (Eq. CP1). Where $QD_{c,u,r}$ is the quantity of the domestic commodity demanded by domestic consumers, $QM_{c,u,r}$ the quantity of composite imports and $QQ_{c,u,r}$ the quantity of the composite commodity. Notice how the commodity quantities are the weights. This composite commodity price (Eq. CP1) does not include sales taxes, which create price wedges between the purchaser prices of commodities for intermediate ($PINTD_{c,r}$), household consumption ($PCD_{c,r}$), government consumption ($PGD_{c,r}$) and investment ($PINVD_{c,r}$) use and the producer prices ($PQS_{c,u,r}$). Hence the purchaser price is defined as the producer price plus the sales taxes (Eqs. CP2-CP5). This formulation means that the sales taxes are levied on all sales on the domestic market, irrespective of the origin of the commodity concerned.

44. The composite output price for a commodity by use category $PS_{c,u,r}$ is also derived by exploiting Euler's theorem for linearly homogeneous functions, and is given by equation CP3 where $PD_{c,u,r}$ is the domestic producer price for the output of commodities supplied to the domestic market. $QD_{c,u,r}$ is the supply of output to the domestic market, $QE_{c,u,r}$ is the quantity exported by activities, and $QS_{c,u,r}$ is the quantity of domestic production by commodity and use category. It is also necessary to define a price numéraire for each region; for this model two alternative numéraire are defined so as to allow the modeller some discretion as to the choice of numéraire[12]. The consumer price indices (CPI_r) are defined as base weighted sum of the household demand commodity prices including value added tax, where the weights are the value shares of each commodity in final household demand ($vqcdsh_{c,r}$) (Eq. N1).

12 The price index not used as the numéraire provides useful additional information when interpreting the results.

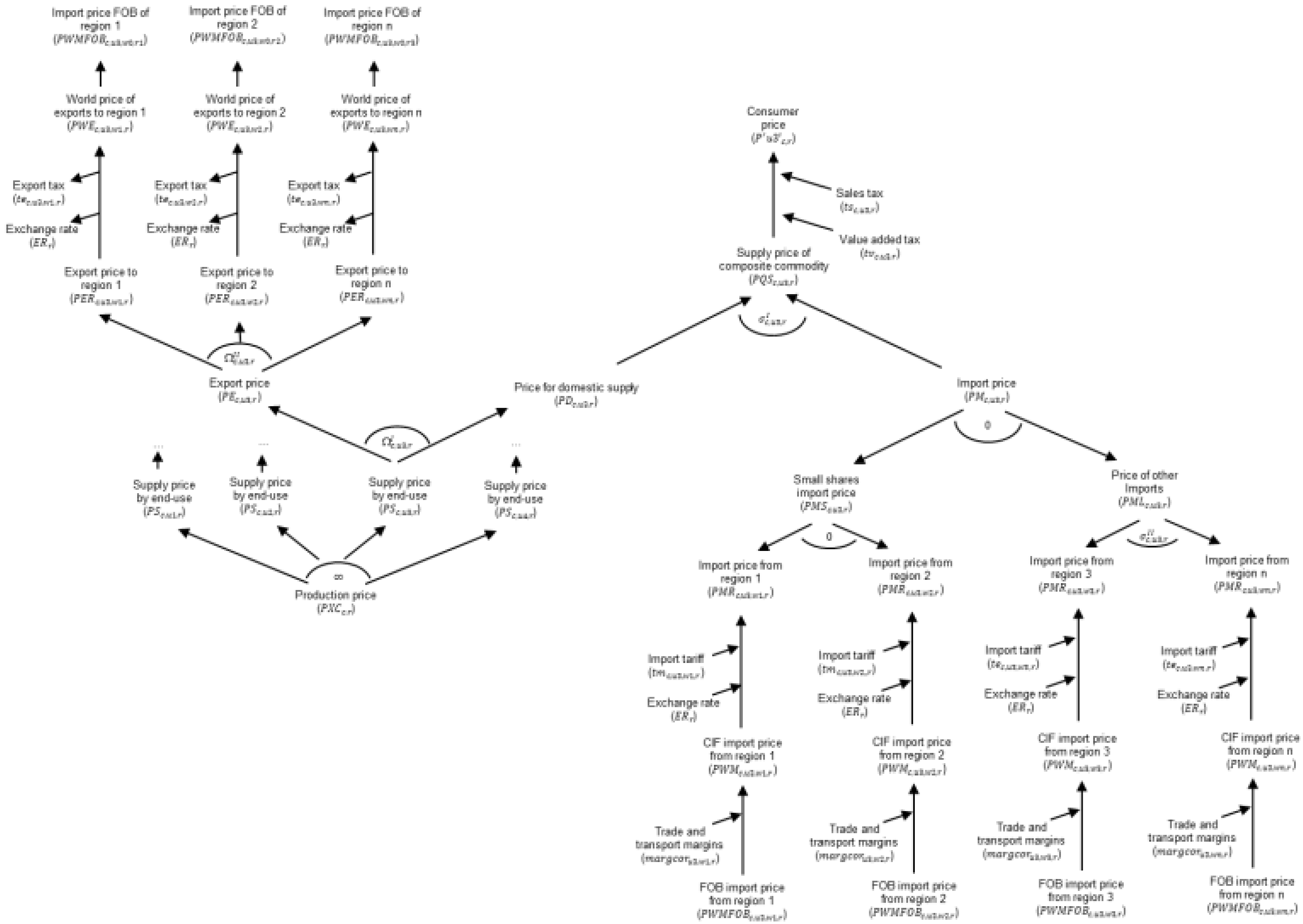
	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Commodity Price Block			
(CP1)	$PQSDEF_{c,u,r}$	$PQS_{c,u,r} = \frac{PD_{c,u,r} * QD_{c,u,r} + PM_{c,u,r} * QM_{c,u,r}}{QQ_{c,u,r}}$	(c*u*rgn)	$PQS_{c,u,r}$	No
(CP2)	$PINTDDEF_{c,r}$	$PINTD_{c,r} = PQS_{c,\text{"uint"},r} * (1 + TS_{c,\text{"uint"},r})$	(c*rgn)	$PINTD_{c,r}$	No
(CP3)	$PCDDEF_{c,r}$	$PCD_{c,r} = PQS_{c,\text{"uhhd"},r} * (1 + TS_{c,\text{"uhhd"},r})$	(c*rgn)	$PCD_{c,r}$	No
(CP4)	$PGDDEF_{c,r}$	$PGD_{c,r} = PQS_{c,\text{"ugov"},r} * (1 + TS_{c,\text{"ugov"},r})$	(c*rgn)	$PGD_{c,r}$	No
(CP5)	$PINVDDEF_{c,r}$	$PINVD_{c,r} = PQS_{c,\text{"ukap"},r} * (1 + TS_{c,\text{"ukap"},r})$	(c*rgn)	$PINVD_{c,r}$	No
(CP6)	$PSDEF_{c,u,r}$	$PS_{c,u,r} = \frac{PD_{c,u,r} * QD_{c,u,r} + PE_{c,u,r} * QE_{c,u,r}}{QS_{c,u,r}}$	(c*u*rgn)	$PS_{c,u,r}$	No
		Numeraire Price Block			
(N1)	$CPIDEF_r$	$CPI_r = \sum_c \left(vqcdsh_{c,r} * PCD_{c,r} * (1 + TV_{c,r})\right)$	(rgn)	CPI_r	No
(N2)	PPI_r	$PPI_r = \sum_{c,u} (vqdsh_{c,u,r} * PD_{c,u,r})$	(rgn)	PPI_r	No
(N3)	$ERPIDEF$	$ERPI = \sum_{ref} (vqesh_{ref} * ER_{ref})$	1	$ERPI$	No

45. While the domestic producer price indices (PPI_r) are defined as the weighted sums of the commodity prices received by producers on the domestic market, where the weights are the value shares of each commodity supplied by domestic producers to the domestic market ($vddtotsh_{c,u,r}$) (Eq. N2). This provides a convenient alternative price normalization term; if the exchange rate is also fixed it serves to fix the real exchange rate.

46. Notice how both price indices are controlled to be implemented only for those regions that have consumption and production activities. Hence the Globe region does not have its own price indices; rather the price indices for Globe are those of the reference region(s) in the model.

47. The exchange rate numéraire (Eq. N3) is defined as an exchange rate index for the set *ref*, which allows the user to define the reference region(s) for the exchange rate. The reference region can consist of a single region or a group of regions. Experience suggests that model performance is improved by including several regions in *ref*; typically this is done with a basket of regions containing the OECD members but other alternatives are possible. Fixed country trade balances must be seen as specified in 'real' terms defined by the global numéraire. Thus, if the US exchange rate is fixed to one, the global numéraire is defined as US dollars, and all trade balances can be seen as 'real' variables defined in terms of the value of US exports. If the weighted exchange rate for a group of regions is chosen as global numéraire, trade balances can be seen as a 'claim' against a weighted average of exports by the group of regions.

Figure 3. Price structure of commodity market by use category



Source: Authors' compilation based on McDonald et al. 2013.

1.3.4 Production[13]

Production

48. The production system is set up as a three level nest of CES production functions, schematically depicted in Figure 4. At the top level aggregate intermediate inputs ($QINT_{a,r}$) are combined with aggregate primary inputs ($QVA_{a,r}$) to produce the output of an activity ($QX_{a,r}$). This top level production function can take either CES or Leontief form, with CES being the default and the elasticities being activity and region specific.[14] Aggregate intermediate inputs are a Leontief aggregation of the individual intermediate inputs where the input-output coefficients ($ioqint_{a,c,r}$) are defined in terms of input quantities relative to the aggregate intermediate input. The value added production function is a standard CES function over an capital and skilled labour aggregate, land, natural resources and aggregate unskilled labour. The setup of the nesting is flexible. The set of primary inputs (*ff*) includes all the natural primary inputs in GTAP v81.L (capital, land, natural resources and 5 skilled and unskilled labour categories) plus the two factor aggregates, where the natural inputs make up the set *f*. The notation for all primary inputs, natural and aggregates, is the same: quantity demand is $FD_{ff,a,r}$, quantity supplied is $FS_{ff,r}$ and the factor prices is $WF_{ff,r}$. The operation of this aggregator function can, of course, be influenced by choices over the closure rules for the factor accounts.

49. In the price system for production, displayed schematically in Figure 5, the value added prices ($PVA_{a,r}$) are determined by the activity prices ($PX_{a,r}$), the production tax rates ($TX_{a,r}$), the input-output coefficients ($ioqint_{a,c,r}$) and the commodity prices of intermediate inputs ($PINTD_{c,r}$). The activity prices are a one to one mapping of the (composite in use dimension) commodity prices received by activities ($PXC_{c,r}$); this is a consequence of the supply matrix being a square diagonal matrix.

Top level

50. The output price by activity ($PX_{a,r}$) is defined by the shares of commodity outputs produced by each activity (Eq. P1.1) where, for this case, the weights ($ioqxcqx_{a,c,r}$) are equal to one where the commodities and activities match and zero. Otherwise there is a one to one mapping between the commodity and activity accounts. The weights are derived from the information in the supply or make matrix.[15]

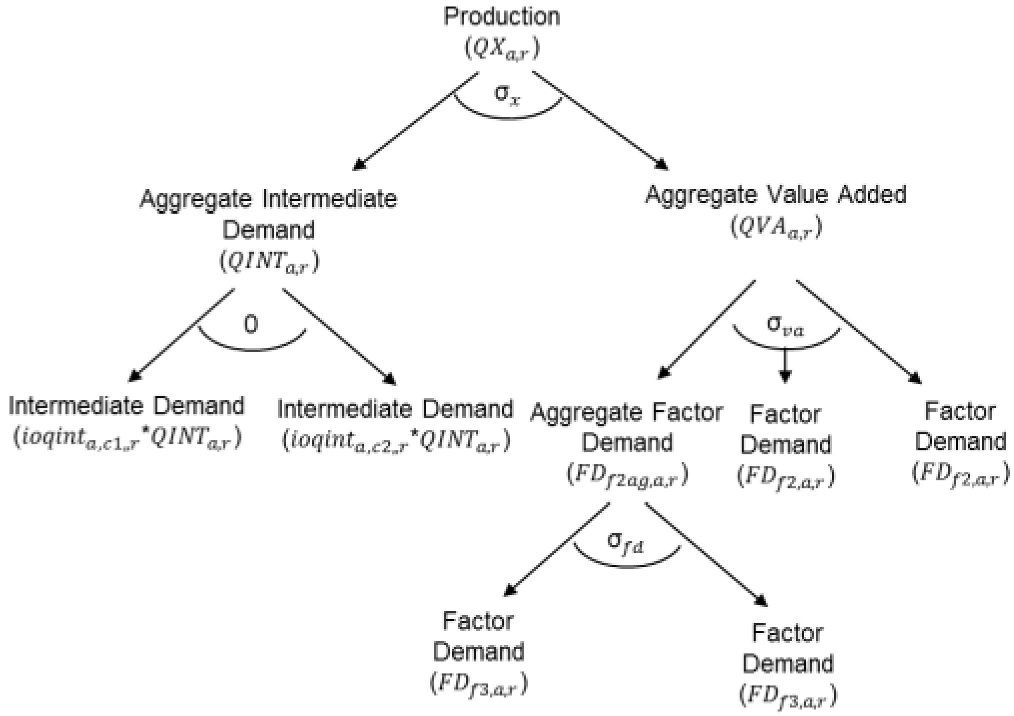
51. The value of output by activity is defined as the activity price ($PX_{a,r}$) less production taxes ($TX_{a,r}$) times the volume of output ($QX_{a,r}$). This revenue must be divided between payments to primary inputs – the price of value added ($PVA_{a,r}$) times the quantity of value added ($QVA_{a,r}$) – and intermediate inputs – the price of aggregate intermediate inputs ($PINT_{a,r}$) times the volume of aggregate intermediate inputs ($QINT_{a,r}$) (Eq. P1.2). Given the assumption that intermediate inputs are used in fixed (volume) proportions, the price of aggregate intermediate inputs ($PINT_{a,r}$) is defined as the weighted average price of the intermediate inputs where the weights are the (normalised) input-output coefficients (Eq. P1.3).

13 As the production structure of METRO and its parent GLOBE model is identical, this section is largely identical to McDonald et al. (2013).

14 The model allows the user to specify the share of intermediate input cost in total cost below which the Leontief alternative is automatically selected. The user also has the option to make activity and region specific decisions about the selection of CES or Leontief forms.

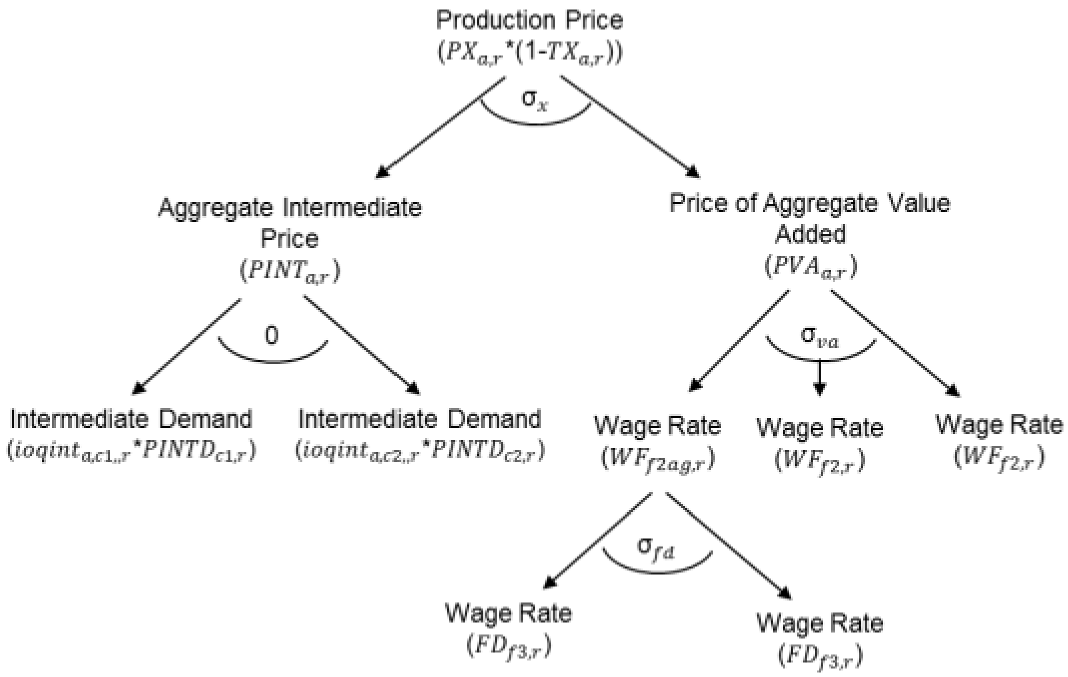
15 When using GTAP data, $ioqxcqx_{a,c,r}$ is always a diagonal matrix.

Figure 4. Production quantity system



Source: Authors' compilation based on McDonald et al. 2013.

Figure 5. Production price system



Source: Authors' compilation based on McDonald et al. 2013.

Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
	Production block – Top level			
(P1.1) $PXDEF_{a,r}$	$PX_{a,r} = \sum_{c}\left(ioqxcqx_{a,c,r} * PXC_{c,r}\right)$	(a*rgn)	$PX_{a,r}$	No
(P1.2) $PVADEF_{a,r}$	$PX_{a,r} * (1 - TX_{a,r}) * QX_{a,r} = PVA_{a,r} * QVA_{a,r} + PINT_{a,r} * QINT_{a,r}$	(a*rgn)	$PVA_{a,r}$	No
(P1.3) $PINTDEF_{a,r}$	$PINT_{a,r} = \sum_{c}\left(ioqint_{a,c,r} * PINTD_{c,r}\right)$	(a*rgn)	$PINT_{a,r}$	No
(P1.4) $ADXEQ_{a,r}$	$ADX_{a,r} = \left(adxb_{a,r} + dabadx_{a,r}\right) * ADXADJ_{r} * adxadj01_{a,r} + DADX_{r} * adx01_{a,r}$	(a*rgn)	$ADX_{a,r}$	No
(P1.5) $QXPRODFN_{a,r}$	$QX_{a,r} = ADX_{a,r} * \left(deltax_{a,r} * QVA_{a,r}^{-rhox_{a,r}} + \left(1 - deltax_{a,r}\right)QINT_{a,r}^{-rhox_{a,r}}\right)^{\left(\frac{-1}{rhox_{a,r}}\right)}$	(aqx*rgn)	$QX_{a,r}$	No
(P1.6) $QXFOC_{a,r}$	$QVA_{a,r} = QINT_{a,r} * \left(\frac{PINT_{a,r}}{PVA_{a,r}} * \frac{deltax_{a,r}}{1 - deltax_{a,r}}\right)^{\left(\frac{1}{1+rhox_{a,r}}\right)}$	(aqx*rgn)	$QINT_{a,r}$	No
(P1.7) $QINTDEF_{a,r}$	$QINT_{a,r} = ioqintqx_{a,r} * QX_{a,r}$	(aqxn*rgn)	$QX_{a,r}$	No
(P1.8) $QVADEF_{a,r}$	$QVA_{a,r} = ioqvaqx_{a,r} * QX_{a,r}$	(aqxn*rgn)	$QINT_{a,r}$	No
(P1.9) $COMOUT_{c,r}$	$QXC_{c,r} = \sum_{a}\left(ioqxcqx_{a,c,r} * QX_{a,r}\right)$	(c*rgn)	$QXC_{c,r}$	No

52. The default top level production function (Eq. P1.5) is a CES aggregation of aggregate primary and intermediate inputs, where the first order conditions for profit maximization (Eq. P1.6) determine the optimal ratio of the inputs. The efficiency factor ($ADX_{a,r}$) and the factor shares parameters ($deltax_{a,r}$) are calibrated from the data and the elasticities of substitution, from which the substitution parameters are derived ($rhox_{a,r}$), are exogenously imposed. Note in this case the efficiency factor is declared as variable and is determined by (Eq. P1.4), where $adxb_{a,r}$ is the vector of efficiency factors in the base solution, $dabadx_{a,r}$ is a vector of absolute changes in the vector of efficiency factors, $ADXADJ_r$ is a variable whose initial value is one, $DADX_r$ is a variable whose initial value is zero and $adx01_{a,r}$ is a vector of zeroes and non-zeroes.[16] In the base solution the values of $adxb_{a,r}$ and $dabadx_{a,r}$ are all zero and $ADXADJ_r$ and $DADX_r$ are fixed as their initial values – a closure rule decision –then the applied efficiency factors are those from the base solution. This formulation allows flexibility in the formulation of the efficiency parameter that is especially useful in the context of a dynamic model – the structure of the equation is identical to that used for the tax rate equations and a description of its operation is provided when describing the tax rate equations.

53. The production function (Eq. P1.5) is only implemented for members of the set *aqx*; for its complement *aqxn* the CES function is replaced by Leontief functions. These require that aggregate intermediate inputs (Eq. P1.7) and aggregate values added (Eq. P1.8) are fixed proportions of the volumes

16 Typically the values are either one or zero, i.e., the adjustment factor is switched on or off. Non zero values other than one switch on the adjustment factor and allow a more complex set of adjustments although it is important to be careful about the rationale for such a set of adjustments.

of output. If there are no intermediate inputs used by an activity, the top level functions is automatically Leontief, and the user is able to determine the minimum costs share of intermediate inputs below which the Leontief assumption is imposed automatically after the user defines the share – the default is 10%.[17]

54. Finally it is necessary to define the relationship between activity and commodity outputs, which is the counterpart to the price equation linking commodity and activity prices (Eq. P1.1). This is defined as a simple linear relationship whereby the commodity output is defined as the sum of the quantities of each commodity produced by each activity (Eq. P1.9). Given the underlying data, where each activity only produces a single commodity and $ioqxqxc_{a,c,r}$ is an identity matrix, equation P1.9 simply maps activities to commodities and vice versa.

Second and third level

55. The second and third level production functions use factors of production ($FD_{f,a,,r}$) that are defined over the set *ff* of which the natural factors, set *f*, are a subset and the other members of *ff* are aggregate factors.[18] Given the structure of the underlying database this variant of the METRO model is specified so that the aggregate factors are an capital and skilled labour aggregate and (aggregate) unskilled labour[19], which are defined at the third level, while the second level defines the production function for value added ($QVA_{a,r}$) that uses aggregate labour factors and all the other natural factors of production, i.e., land and natural resources. The second level production functions are CES aggregation functions over the natural and aggregate factors that are demanded by each activity ($FD_{f2,a,r}$), with efficiency factors ($ADVA_{a,r}$) and the factor shares ($deltava_{f2,a,,r}$) calibrated from the data and the elasticities of substitution, from which the substitution parameters are derived ($rhova_{a,r}$), are exogenously imposed (Eq. P2.3). Note how the production function for $QVA_{a,r}$ is specified to use the sub set *f2(ff)* of factors; this set includes the capital and labour aggregates, unskilled aggregate and land and natural resources. The associated first-order conditions for optimal factor combinations are derived from equalities between the wage rates for each factor in each activity and the values of the marginal products of those factors in each activity (Eq. P2.4); while defined over *ff* its operation is limited to *f2*. The actual wage rate for a specific factor used by a specific activity is defined as the average wage rate for that factor ($WF_{ff,r}$) times a factor and activity specific factor 'efficiency' parameter ($WFDIST_{ff,a,r}$); these ratios of payments to factor *ff* from activity *a* are included to allow for non-homogenous factors where the differentiation is defined solely in terms of the activity that employs the factor. However, the actual returns to a factor must be adjusted to allow for taxes on factor use ($TF_{ff,a,r}$).

56. The efficiency factors are declared as variables (Eq. P2.1), where $advab_{a,r}$ is the vector of efficiency factors in the base solution, $dabadva_{a,r}$ is a vector of absolute changes in the vector of efficiency factors, $ADVAADJ_r$ is a variable whose initial value is one, $DADVA_r$ is a variable whose initial value is zero and

17 The minimum cost share of intermediate inputs is determined in the 'controls' sheet of the data excel workbook.

18 Since only natural factors *f* receive actual income the use of the set *ff* in the production modules allows the set *f* to control the distribution of factor incomes. Similarly it should be noted that only natural factors should be subjected to factor use taxes (*TF*).

19 In the fully disaggregated database the labour categories and capital are not differentiated across activities while land and natural resources are segmented, i.e., no activity employs both land and natural resources. For METRO it is recommended that natural factors are not aggregated and in particular that land and natural resources are *never* aggregated *and* that aggregates are not formed across activities that use land and natural resources in the disaggregated data.

$adva01_{a,r}$ is a vector of zeroes and non-zeroes.[20] In the base solution the values of $advab_{a,r}$ and $dabadva_{a,r}$ are all zero and $ADVAADJ_r$ and $DADVA_r$ are fixed as their initial values – a closure rule decision – then the applied efficiency factors are those from the base solution. A similar specification is adopted for factor specific efficiency factors, i.e., factor that can alter/adjust the stock-flow relationship between factor quantities and factor services, although it differs in the adjustment mechanism (Eq. P2.2). Specifically only a multiplicative variant is defined and then three adjustment variables are defined that allow for factor specific ($ADFDfADJ_f$), activity specific ($ADFDaADJ_a$) and regions specific ($ADFDrADJ_r$) adjustments.

Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
	Production block – Second level			
(P2.1) $ADVAEQ_{a,r}$	$ADVA_{a,r} = \left(advab_{a,r} + dabadva_{a,r}\right) * ADVAADJ_r * advaadj01_{a,r} + DADVA_r * adva01_{a,r}$	(a*rgn)	$ADVA_{a,r}$	No
(P2.2) $ADFDEQ_{f,a,r}$	$ADFD_{f,a,r} = \left(adfdb_{f,a,r} + dadfd_{f,a,r}\right) * ADFDfADJ_f * ADFDaADJ_a * ADFDrADJ_r$	(f*a*rgn)	$ADFD_{f,a,r}$	No
(P2.3) $QVAPRODFN_{a,r}$	$QVA_{a,r} = ADVA_{a,r} * \left[\sum_{f2}\left(deltava_{f2,a,r}\left(ADFD_{f2,a,r}FD_{f2,a,r}\right)^{-rhova_{a,r}}\right)\right]^{\left(\frac{-1}{rhova_{a,r}}\right)}$	(a*rgn)	$QVA_{a,r}$	No
(P2.4) $QVAFOC_{ff,a,r}$	$WF_{ff,r} * WFDIST_{ff,a,r} * \left(1 + TF_{ff,a,r}\right) = PVA_{a,r} * QVA_{a,r} * \left[\sum_{ff}\left(deltava_{ff,a,r}\left(ADFD_{ff,a,r}FD_{ff,a,r}\right)^{-rhova_{a,r}}\right)\right]^{-1} * deltava_{ff,a,r} * ADFD_{ff,a,r}^{-rhova_{a,r}} * FD_{ff,a,r}^{(-rhova_{a,r}-1)}$	(f2,a,rgn)	$FD_{f2,a,r}$	No
(P2.5) $QINTDEQ_{c,r}$	$QINTD_{c,r} = \sum_{a}\left(ioqint_{c,a,r} * QINT_{a,r}\right)$	(c*rgn)	$QINTD_{c,r}$	No
	Production block – Third level			
(P3.1) $FDPRODFN_{ff,a,r}$	$FD_{ff,a,r} = adfag_{ff,a,r} * \left[\sum_{l}\left(deltafd_{ff,l,a,r} * FD_{l,a,r}^{-rhofd_{ff,a,r}}\right)\right]^{\left(\frac{-1}{rhofd_{ff,a,r}}\right)}$	(fag*a*r)	$FD_{fag,a,r}$	No
(P3.2) $FDFOC_{ff,l,a,r}$	$WF_{l,r} * WFDIST_{l,a,r} * \left(1 + TF_{l,a,r}\right) = WF_{ff,r} * WFDIST_{ff,a,r} * \left(1 + TF_{ff,a,r}\right) * FD_{ff,a,r} * \left[\sum_{l}\left(deltafd_{ff,l,a,r} * FD_{l,a,r}^{-rhofd_{ff,a,r}}\right)\right]^{-1} * deltafd_{ff,l,a,r} * FD_{ff,a,r}^{(-rhofd_{ff,a,r}-1)}$	(l*a*r)	$FD_{l,a,r}$	No

57. Since production uses intermediate inputs, it is also necessary to specify the demand for intermediate inputs ($QINTD_{c,r}$). This is done from the perspective of commodity demands, i.e., it is summed over activities to produce the demand for intermediate inputs by commodity rather than by activity (Eq. P2.5).

20 Typically the values are either one or zero, i.e., the adjustment factor is switched on or off. Non zero values other than one switch on the adjustment factor and allow a more complex set of adjustments although it is important to be careful about the rationale for such a set of adjustments.

58. The third level production functions (Eq. P3.1) define the quantities of aggregate factors fag as CES aggregates of the labour factors *l*. As elsewhere the efficiency factors ($adfag_{fag,a,r}$)[21] and the factor shares ($deltafd_{fag,l,a,r}$) calibrated from the data and the elasticities of substitution, from which the substitution parameters are derived, are exogenously imposed. The matching first order conditions (Eq. P3.2) defines the wage rate for a specific factor used by a specific activity as the average wage rate for that factor ($WF_{l,r}$) times a factor and activity specific factor 'efficiency' parameter ($WFDIST_{l,a,r}$); these ratios of payments to factor *l* from activity *a* are included to allow for non-homogenous factors where the differentiation is defined solely in terms of the activity that employs the factor. However the actual returns to a factor must be adjusted to allow for taxes on factor use ($TF_{l,a,r}$).

Factors

59. The total income received by each factor account ($YF_{f,r}$) is defined as the summation of the earnings of that factor across all activities (Eq. F1). However, only a proportion of total factor income is available for distribution to the domestic institutional accounts ($YFDIST_{f,r}$). First, allowance must be made for depreciation, which it is assumed takes place at fixed rates ($deprec_{f,r}$) relative to factor incomes and the payment of factor income taxes ($TYF_{f,r}$) (Eq. F2).

60. Unemployment is introduced as mixed complementarity problem (MCP) (Eq. F3). The total supply of a natural factor consists of current total demand and a stock of the factor that is currently unemployed ($UNEMP_{f,r}$) (Eq. MC2.1). When there is unemployment, the real wage of that factor is fixed until all unemployed factors are absorbed by demand in the labour market. When the stock of unemployed factors is empty, the real wage rate of this factor is flexible. Thus two segments of labour supply functions are generated: horizontal until full employment and then vertical. A minimum wage rate can be established setting a lower level to the wage rate.

Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
	Factor Market Block			
(F1) $YFEQ_{f,r}$	$YF_{f,r} = \sum_{a}\left(WF_{f,r} * WFDIST_{f,a,r} * FD_{f,a,r}\right)$	(f*rgn)	$YF_{f,r}$	No
(F2) $YFDISTEQ_{f,r}$	$YFDIST_{f,r} = \left(YF_{f,r} - deprec_{f,r} * YF_{f,r}\right) * \left(1 - TYF_{f,r}\right)$	(f*rgn)	$YFDIST_{f,r}$	No
(F3) $UNEMPEQUIL_{f,r}$	$UNEMP_{f,r} \geq 0$	(f*rgn)	$UNEMP_{f,r}$	No
	$WF0_{f,r} \leq WF_{f,r} \leq +\infty \quad \forall uef$			

1.3.5 Institutions[22]

Households

61. Households *h* acquire income from only one source in this model, the sale of factor services. Therefore household income ($YH_{h,r}$) is defined simply as the sum of factor incomes available for distribution (Eq. H1). In this variant allowance is made for the possibility of multiple households by

21 Note that, unlike the other efficiency factors, $adfag_{fag,a,r}$ is not specified as variable.

22 As the depiction of institutions in METRO and its parent GLOBE model is identical, this section is mainly identical to McDonald et al. (2013).

including a set of distribution parameters ($hvash_{h,f,r}$) that are defined as the shares of each factor demanded in the economy that is supplied by each household. In the case of one household all the shares equal one.

62. Household consumption demand is derived in two stages. In the first stage (Eq. H2) household consumption expenditures ($HEXP_{h,r}$) are defined as household incomes after the payment of direct taxes and savings and inter household transfers. Note how the saving rates are defined as proportions of after tax incomes that are saved; this is important for the calibration of the income tax and savings parameters.

63. The household utility functions are assumed to be Stone-Geary, i.e., a linear expenditure system, which means that household consumption demand consists of two components, 'subsistence' demand ($qcdconst_{c,h,r}$) and 'discretionary' demand, and the equation must therefore capture both elements (Eq. H3). Discretionary demand is defined as the marginal budget shares ($beta_{c,h,r}$) spent on each commodity out of 'uncommitted' income, i.e., household consumption expenditure less total expenditure on 'subsistence' demand. The quantities of each commodity demanded by the household are then defined by the shares of household consumption expenditure. The Stone-Geary function collapses to a Cobb-Douglas utility function if all the income elasticities of demand are set equal to one and the Frisch parameter, the elasticity of the marginal utility of income, is also set to one. One advantage of the Cobb- Douglas specification is that it results in the changes in the values for household consumption expenditures ($HEXP_{h,r}$) being equal to the changes in an equivalent variation measure of household welfare.

Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
	Household Block			
(H1) $YHEQ_{h,r}$	$YH_{h,r} = \sum_{f} \left(hvash_{h,f,r} * YFDIST_{f,r} \right)$	(h*rgn)	$YH_{h,r}$	No
(H2) $HEXPEQ_{h,r}$	$HEXP_{h,r} = \left(YH_{h,r} * \left(1 - TYH_{h,r}\right)\right) * \left(1 - SHH_{h,r}\right)$	(h*rgn)	$HEXP_{h,r}$	No
(H3) $QCDEQ_{c,h,r}$	$PCD_{c,r} * QCD_{c,h,r}\left(1 + TV_{c,r}\right) = \left(PCD_{c,r} * qcdconst_{c,h,r}\left(1 + TV_{c,r}\right)\right) + beta_{c,h,r} * \left[HEXP_{h,r} - \sum_{c} \left(PCD_{c,r} * qcdconst_{c,h,r}\left(1 + TV_{c,r}\right)\right)\right]$	(c*h*rgn)	$QCD_{c,h,r}$	No

Government Taxes

64. There are nine tax instruments. Eight are defined as a simple ad valorem rate dependent upon the values of imports, exports, sales, production and factor use by activities and the levels of factor and household income. One is a specific tariff. The 'tax' rates are all declared as variables. All tax rates are variables in this model and for each tax instrument a series of factors are declared to facilitate policy experiments. The tax rates in the base solution are defined as parameters, e.g., $tm0_{w,c,r}$ are the import tariff rates by commodity *c* and use category *u* imported from region *w* in region *r* in the base solution. The tax rate equations then allow for varying the tax rates in four different ways. Two of the methods use variables that can be solved for optimum values in the model according to the choice of closure rule and two methods allow for deterministic adjustments to the structure of the tax rates. The operations of these methods are discussed in detail only for the equations for import duties while the other equations are simply reported.

65. In the import tariff rate equation (Eq. T1.1) $tm0_{w,c,u,r}$ is the vector of import duties in the base solution, $dabtm_{w,c,u,r}$, is a vector of absolute changes in the vector of import duties taxes, $TMADJ_r$ is a region specific variable whose initial value is one, DTM_r is a region specific variable whose initial value is zero and $tm01_{w,c,u,r}$ is a vector of zeroes and non-zeroes. In the base solution the values of $tm01_{w,c,u,r}$ and $dabtm_{w,c,u,r}$ are all zero and $TMADJ_r$ and DTM_r are fixed as their initial values – this is a closure rule decision. Given this decision the model treats the tax rates as (fixed) parameters and the applied import tariffs are those from the base solution. The different methods of adjustment can be considered in turn.

1. If $TMADJ_r$ for one region is made a variable, which requires the fixing of another variable for that region, and all other initial conditions hold then the solution value for $TMADJ_r$ yields the optimum equiproportionate change in the import duty rates necessary to satisfy model constraints, e.g., if $TMADJ_r$ equals 1.1 then all applied (non-zero) import duty rates (that are found in the base data) for the specified region are increased by 10%.

2. If any element of $dabtm_{w,c,u,r}$ is not zero, and all the other initial conditions hold, then an absolute change in the initial import tariff rate for the relevant commodity is imposed, e.g. if $tm0_{w,c,u,r}$ for one element of *c* is 0.1 (a 10% import duty) and $dabtm_{w,c,u,r}$ for that element is 0.05, then the applied import tariff rate is 0.15 (15%).

3. If $TMADJ_r$ for one region is made a variable, which requires the fixing of another variable for that region, any elements of $dabtm_{w,c,u,r}$ are non-zero and all other initial conditions hold, then the solution value for $TMADJ_r$ yields the optimum equiproportionate change in the applied import duty rates, i.e. $tm0_{w,c,u,r}+dabtm_{w,c,u,r}$ (and these applied rates can be different from those in the base in which $dabtm_{w,c,u,r}$ is set at zero).

4. If DTM_r for one region is made a variable, which requires the fixing of another variable for that region, AND at least one element of $tm01_{w,c,u,r}$ is ONE then the subset of elements of $tm0_{w,c,u,r}$ identified by $tm01_{w,c,u,r}$ are allowed to (additively) increase by an equiproportionate amount determined by the solution value for DTM_r and the initial values of the import duty rates, e.g., if food products are to be excluded from the change in tax rates then the elements of $tm01_{w,c,u,r}$ corresponding to the food commodities are (left as) zeroes. Note how in this case it is necessary to both 'free' a variable and give values to a parameter for a solution to emerge. If the change in the applied tax rates is to be other than equiproportionate then values of $tm01_{w,c,u,r}$ other than one can be applied, e.g. if the changes in the import duties on food products are to be half those on other sectors then the elements of $tm01_{w,c,u,r}$ corresponding to the food commodities can be set to 0.5 and for the other commodities can be set to 1.

	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Government Tax Rates Block			
(T1.1)	$TMDEF_{w,c,u,r}$	$TM_{w,c,u,r} = \left(tmb_{w,c,u,r} + dabtm_{w,c,u,r}\right) * TMADJ_r + DTM_r * tm01_{w,c,u,r}$	(w*cmr*u*r)	$TM_{w,c,u,r}$	Yes
(T1.2)	$TMSDEF_{w,c,u,r}$	$TMS_{w,c,u,r} = \left(tmsb_{w,c,u,r} + dabtms_{w,c,u,r}\right) * TMSADJ_r + DTMS_r * tms01_{w,c,u,r}$	(w*cmr*u*r)	$TMS_{w,c,u,r}$	Yes
(T1.3)	$TEDEF_{c,u,w,r}$	$TE_{c,u,w,r} = \left(teb_{c,u,w,r} + dabte_{c,u,w,r}\right) * TEADJ_r + DTE_r * te01_{c,u,w,r}$	(cer*u*w*r)	$TE_{w,c,u,r}$	Yes
(T1.4)	$TSDEF_{c,u,r}$	$TS_{c,u,r} = \left(tsb_{c,u,r} + dabts_{c,u,r}\right) * TSADJ_r + DTS_r * ts01_{c,u,r}$	(c*u*rgn)	$TS_{c,u,r}$	No
(T1.5)	$TVDEF_{c,r}$	$TV_{c,r} = \left(tvb_{c,r} + dabtv_{c,r}\right) * TVADJ_r + DTV_r * tv01_{c,r}$	(c*rgn)	$TV_{c,r}$	No
(T1.6)	$TXDEF_{a,r}$	$TX_{a,r} = \left(txb_{a,r} + dabtx_{a,r}\right) * TXADJ_r + DTX_r * tx01_{a,r}$	(a*rgn)	$TX_{a,r}$	No
(T1.7)	$TYFDEF_{f,r}$	$TYF_{f,r} = \left(tyfb_{f,r} + dabtyf_{f,r}\right) * TYFADJ_r + DTYF_r * tyf01_{f,r}$	(f*rgn)	$TYF_{f,r}$	No
(T1.8)	$TYHDEF_{h,r}$	$TYH_{h,r} = \left(tyhb_{h,r} + dabtyh_{h,r}\right) * TYHADJ_r + DTYH_r * tyh01_{h,r}$	(h*rgn)	$TYH_{h,r}$	No
(T1.9)	$TFDEF_{f,a,r}$	$TF_{f,a,r} = \left(tfb_{f,a,r} + dabtf_{f,a,r}\right) * TFADJ_r + DTF_r * tf01_{f,a,r}$	(f*a*rgn)	$TF_{f,a,r}$	No

66. This combination of alternative adjustment methods covers the range of common tax rate adjustments used in the majority of applied applications while being flexible and easy to use. However experience has shown that when working with GTAP derived data it is very important to check the tax rates that are applied in the base solution; in some aggregations some of the applied tax rates only differ marginally from zero but are a mix of negatives and positives, in such cases it may be necessary to exogenously reset the tax rates to avoid apparently odd results.

67. The other tax rate equations follow the same structure. Specific import duties ($TMS_{c,u,r}$) are defined in in (Eq. T1.2), export taxes ($TE_{c,u,r}$) are defined in (Eq. T1.3), sales taxes ($TS_{c,u,r}$) are defined in (Eq. T1.4), VAT ($TV_{c,r}$) rates are defined in (Eq. T1.5), production tax rates ($TX_{a,r}$) are defined in (Eq. T1.6), factor income tax rates ($TYF_{f,r}$) are defined in (Eq. T1.7), household income rates ($TYH_{h,r}$) are defined in (Eq. T1.8) and factor use tax rates ($TF_{f,r}$) are defined in (Eq. T1.9).

68. The government tax revenue equations simply sum the revenues from each different tax instrument for each region. These are not strictly necessary for the model since the equations could be collapsed into a single government income equation (see Eq. G1 below). However it is useful to carry around these additional variables since they can then be used in model closures to accommodate specific government tax revenue objectives and they are useful sources of information when analysing simulation results.[23]

[23] It is a simple matter to generate such aggregates from model results as part of the reported output of the simulations. The trade-off between the increase in model 'size' associated with extra variables and reduction in the size of the files that generate results is a matter of judgment; the general approach used here is to include as variable such aggregates that may have substantive benefits in terms of transparency and simulation formulation.

69. Import duty revenues ($MTAX_r$) are defined as total import duty revenue in region *r* (Eq. T2.1); specific Import duty revenues ($MSTAX_r$) are defined as total specific import duty revenues in region *r* (Eq. T2.22); export tax revenues ($ETAX_r$) are defined as total export tax revenue in region *r* (Eq. T2.3); sales tax revenues ($STAX_r$) are defined as total sales tax revenue in region *r* (Eq. T2.44); VAT revenues ($VATAX_r$) are defined as total VAT revenue in region *r* (Eq. T2.5); production tax revenues ($ITAX_r$) are defined as total production tax revenue in region *r* (Eq. T2.6); factor income tax revenues ($FYTAX_r$) are defined as total factor income tax revenue in region *r* (Eq. T2.7); household income tax revenues ($HTAX_r$) are defined as total household income tax revenue in region *r* (Eq. T2.8) and factor use tax revenues ($FTAX_r$) are defined as total factor use tax revenue in region *r* (Eq. T2.9).

	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Government Tax Revenue Block			
(T2.1)	$MTAXEQ_r$	$MTAX_r = \sum_{c,u,w} \left(TM_{w,c,u,r} * PWM_{w,c,u,r} * ER_r * QMR_{w,c,u,r}\right)$	(rgn)	$MTAX_r$	No
(T2.2)	$MSTAXEQ_r$	$MSTAX_r = \sum_{c,u,w} \left(TMS_{w,c,u,r} * PWM_{w,c,u,r} * ER_r * QMR_{w,c,u,r}\right)$	(rgn)	$MSTAX_r$	No
(T2.3)	$ETAXEQ_r$	$ETAX_r = \sum_{c,u,w} \left(TE_{c,u,w,r} * PWE_{c,u,w,r} * ER_r * QER_{c,u,w,r}\right)$	(rgn)	$ETAX_r$	No
(T2.4)	$STAXEQ_r$	$STAX_r = \sum_{c,u} \left(TS_{c,u,r} * PQS_{c,u,r} * QQ_{c,u,r}\right)$	(rgn)	$STAX_r$	No
(T2.5)	$VTAXEQ_r$	$VTAX_r = \sum_{c,h} \left(TV_{c,r} * PCD_{c,r} * QCD_{c,h,r}\right)$	(rgn)	$VTAX_r$	No
(T2.6)	$ITAXEQ_r$	$ITAX_r = \sum_{a} \left(TX_{a,r} * PX_{a,r} * QX_{a,r}\right)$	(rgn)	$ITAX_r$	No
(T2.7)	$FYTAXEQ_r$	$FYTAX_r = \sum_{f} \left(TYF_{f,r} * \left(YF_{f,r} - deprec_{f,r} * YF_{f,r}\right)\right)$	(rgn)	$FYTAX_r$	No
(T2.8)	$HTAXEQ_r$	$HTAX_r = \sum_{h} \left(TYH_{h,r} * YH_{h,r}\right)$	(rgn)	$HTAX_r$	No
(T2.9)	$FTAXEQ_r$	$FTAX_r = \sum_{f,a} \left(TF_{f,a,r} * WF_{f,r} * WFDIST_{f,a,r} * FD_{f,a,r}\right)$	(rgn)	$FTAX_r$	No

Government

70. Government income (YG_r) is defined as the sum of government tax revenues (Eq. G1), where the tax revenues are treated as expenditures by the accounts paying the taxes and hence are defined in the tax block. While this approach adds equations it has the arguable advantage of being more transparent and easier to modify. Note how there is no provision for government to receive incomes form non tax sources in this version; this reflects the fact that in the base GTAP database no such incomes are recorded.

71. Government demand for commodities (Eq. G2) is assumed fixed in real terms, i.e., the volume is fixed, but can be scaled or allowed to vary using an adjustment factor ($QGDADJ_r$). The precise specification depends upon the choice of closure rule (see below). Thereafter Government consumption expenditure (EG_r) is defined as the sum of commodity consumption (Eq. G3). The advantage of separately expressing the volume and value of government expenditures is the increased flexibility it provides in the

choice of closure rules for the government account. This arrangement allows adjustment of government demand either through the volume, or the expenditure or the value share of final demand.

	Name	Equation	Number of Eq. and Var.	Variable	Globe Region
		Government block			
(G1)	$YGEQ_r$	$YG_r = MTAX_r + MSTAX_r + ETAX_r + STAX_r + VTAX_r + ITAX_r + FYTAX_r + HTAX_r + FTAX_r$	(rgn)	YG_r	No
(G2)	$QGDEQ_{c,r}$	$QGD_{c,r} = QGDADJ_r * qgdconst_{c,r}$	(c*rgn)	$QGD_{c,r}$	No
(G3)	$EGEQ_r$	$EG_{c,r} = \sum_c (QGD_{c,r} * PGD_{c,r})$	(rgn)	EG_r	No

Capital Account

72. Income to the capital (savings and investment) account, total savings, comes from household savings (*$HHLDSAV_{h,r}$*), depreciation allowances, government savings (*$KAPGOV_r$*) and the surplus on the capital account of the balance of payments (*$KAPWOR_r$*), and hence is simply defined as the sum of savings by domestic and 'foreign' agents (Eq. K3). In this model the household savings rates are declared as variables (*$SHH_{h,r}$*) that define the proportions of income saved after the payment of income taxes. The savings rate equations (Eq. K1) used the same adjustment structure as used for the tax rate equations; hence *$shh0_{h,r}$* are the base solution savings rates *$dabshh_{h,r}$* are absolute changes in the base savings rates, *$SADJ_r$* are multiplicative adjustment factors, *$DSHH_r$* are additive adjustment factors and *$shh01_{h,r}$* is a matrix of zero and non-zero values that determine for which households and regions the savings rates can adjust additively. Note that household savings are taken out of disposable income (Eq. K2).

73. Government savings are calculated as residual (see the *$KAPGOV_r$* equations, eq. MC3.1, below). The surplus on the capital account (*$KAPWOR_r$*) is defined in terms of the foreign currency (see eq. MC3.4 and eq. MC3.3 below) and therefore the exchange rate appears in this equation (this is a matter of preference).

74. Investment demand is modelled in a similar way to government demand. Demand for commodities (Eq. K4) used in investment is assumed to be in fixed volumes (*$qinvdconst_{c,r}$*) multiplied by an investment-scaling variable (*$IADJ_r$*) that can accommodate changes in the exogenously determined level of investment and/or changes in the availability of funds for investment. The second stage (Eq. K5) captures the price effect by identifying the total value of investment (*$INVEST_r$*). This arrangement allows adjustment of investment demand either through the volume, or the expenditure or the value share of final demand (see below).

	Name	Equation	Number of Eq. and Var.	Variable	Globe Region
		Capital block			
(K1)	$SHHDEF_{h,r}$	$SHH_{h,r} = \left(shhb_{h,r} + dabshh_{h,r}\right) * SADJ_r + DSHH_r * shh01_{h,r}$	(h*rgn)	$SHH_{h,r}$	No
(K2)	$TOTSAVEQ_r$	$TOTSAV_r = \sum_h \left(YH_{h,r} * \left(1 - TYH_{h,r}\right) * SHH_{h,r}\right) + \sum_f \left(deprec_{f,r} * YF_{f,r}\right) + KAPGOV_r + KAPWOR_r * ER_r$	(rgn)	$TOTSAV_r$	No
(K3)	$QINVDEQ_{c,r}$	$QINVD_{c,r} = IADJ_r * qinvdconst_{c,r}$	(c*rgn)	$QINVD_{c,r}$	No
(K4)	$INVESTEQ_r$	$INVEST_r = \sum_c PINVD_{c,r} * QINVD_{c,r}$	(rgn)	$INVEST_r$	No

1.3.6 Trade and transport margins: the Globe region[24]

75. An important feature of the model is the use of the concept of a region known as Globe. While the GTAP database contains complete bilateral information relating to the trade in commodities, i.e., in all cases transactions are identified according to their region of origin and their region of destination, this is not the case for trade in margins services associated with the transportation of commodities. Rather the GTAP database identifies the demand, in value terms, for margin services associated with imports by all regions from all other regions but does not identify the region that supplies the margin services associated with any specific transaction. Consequently the data for the demand side for margin services is relatively detailed but the supply side is not. Indeed the only supply side information is the total value of exports of margin services by each region. The Globe construct allows the model to get around this shortage of information, while simultaneously providing a general method for dealing with any other transactions data where full bilateral information is missing. Thus, the Globe region must not be regarded as a 'regular' region. Simulation results for the Globe region track the effects on global transport margins.

76. The price system for the Globe region is illustrated in Figure 6. On the import side Globe operates like all other regions. The commodities used in trade and transport services are assumed to be differentiated by source region and the proportion of imports accounted for by the source region. Thus a two-level Leontief and CES aggregation nest is used. It is assumed that imports of trade and transport services can potentially incur trade and transport margins ($margcor_{w,cp,c,u,r}$) and face tariffs ($TM_{c,u,r}$); in fact the database does not include any transport margins or tariff data for margin services in relation to the destination region, although they can, and do, incur export taxes levied by the exporting region.

77. The export side is slightly different. In effect the Globe region is operating as a method for pooling differentiated commodities used in trade and transport services and the only differences in the use of trade and transport services associated with any specific import are the quantities of each type of trade service used and the mix of types of trade services. Underlying this is the implicit assumption that each type of trade service used is homogenous, and should be sold therefore at the same price. Hence the export price system for Globe needs to be arranged so that Globe exports at a single price, i.e., there should be an infinite elasticity of substitution between each type of trade service exported irrespective of its destination region. Therefore the average export price ($PE_{c,u,r}$) should equal the price paid by each destination region

24 This section is largely identical to McDonald et al. (2013).

($PER_{c,u,w,r}$), which should equal the export price in world currency units ($PWE_{c,u,w,r}$) and will be common across all destinations ($PT_{c,u,r}$) (Eq. MC1.1).

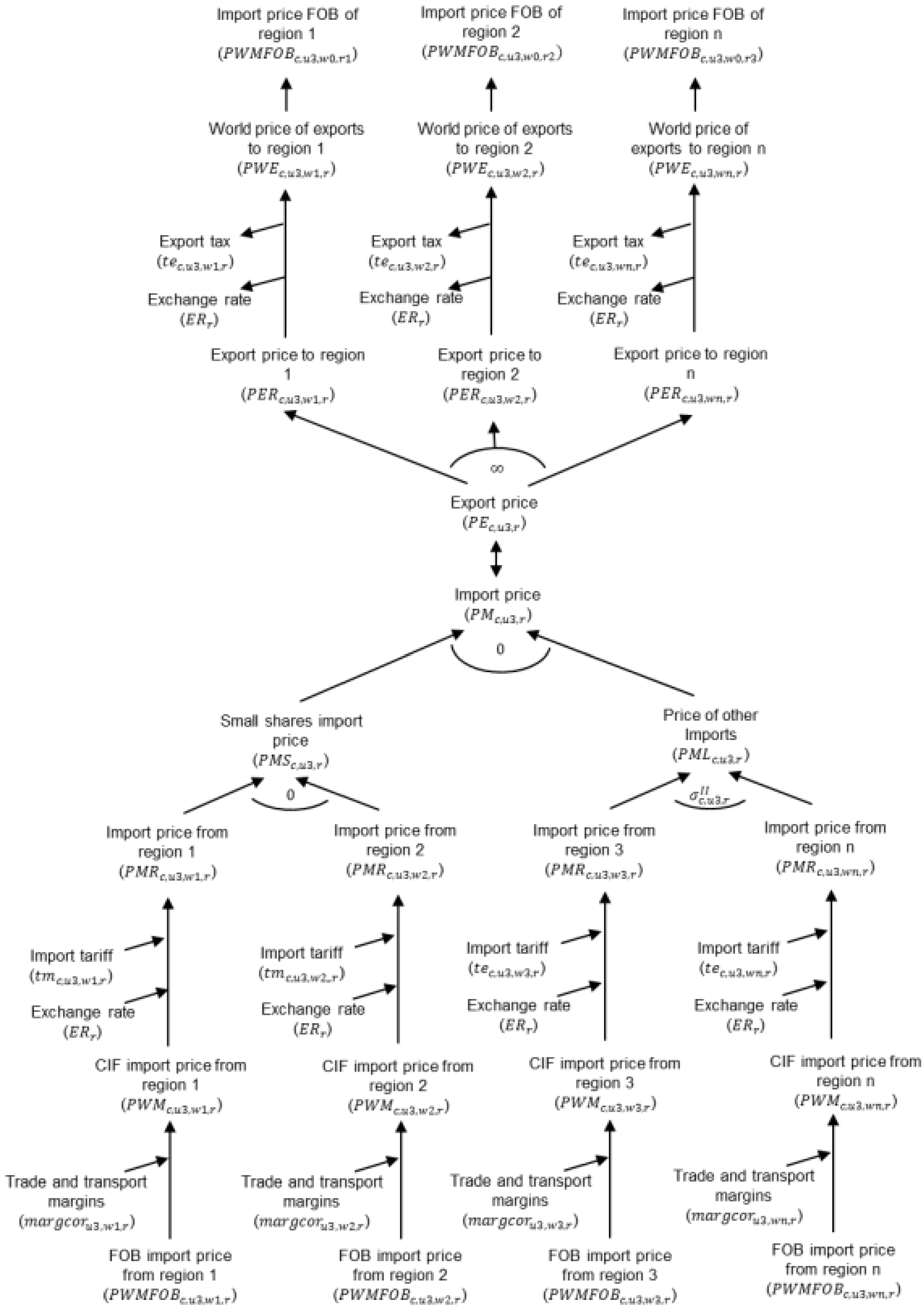
78. The linked quantity system contains the same asymmetry in the treatment of imports and exports by Globe (see Figure 7). The imports of trade and transport commodities are assumed to be differentiated by region and the proportion of imports accounted for by the source region, hence the elasticity of substitution is greater than or equal to zero but less than infinity, while the exports of trade and transport commodities are assumed to be homogenous and hence the elasticities of transformation are infinite.

79. One consequence of using a Globe region for trade and transport services is that Globe runs trade balances with all other regions. These trade balances relate to the differences in the values of trade and transport commodities imported from Globe and the value of trade and transport commodities exported to Globe; however the sum of Globe's trade balances with other regions must be zero since Globe is an artificial construct rather than a real region. But the demand for trade and transport services by any region is determined by technology, i.e., the coefficients $margcor_{w,cp,c,u,r}$, and the volume of imports demanded by the destination region. This means that the prices of trade and transport commodities only have an indirect effect upon their demand – the only place these prices enter into the import decision as a variable is as a partial determinant of the difference between the fob and cif valuations of other imported commodities. Consequently the primary market clearing mechanism for the Globe region comes through the quantity of trade and transport commodities it chooses to import (Eq. MC1.2).

80. The Globe concept has other potential uses in the model. All transactions between regions for which there is an absence of full bilateral information can be routed through the Globe region. While this is not a 'first best' solution, it does provide a 'second best' method by which augmented versions of the GTAP database can be used to enrich the analyses of international trade in a global model prior to availability of full bilateral transactions data.

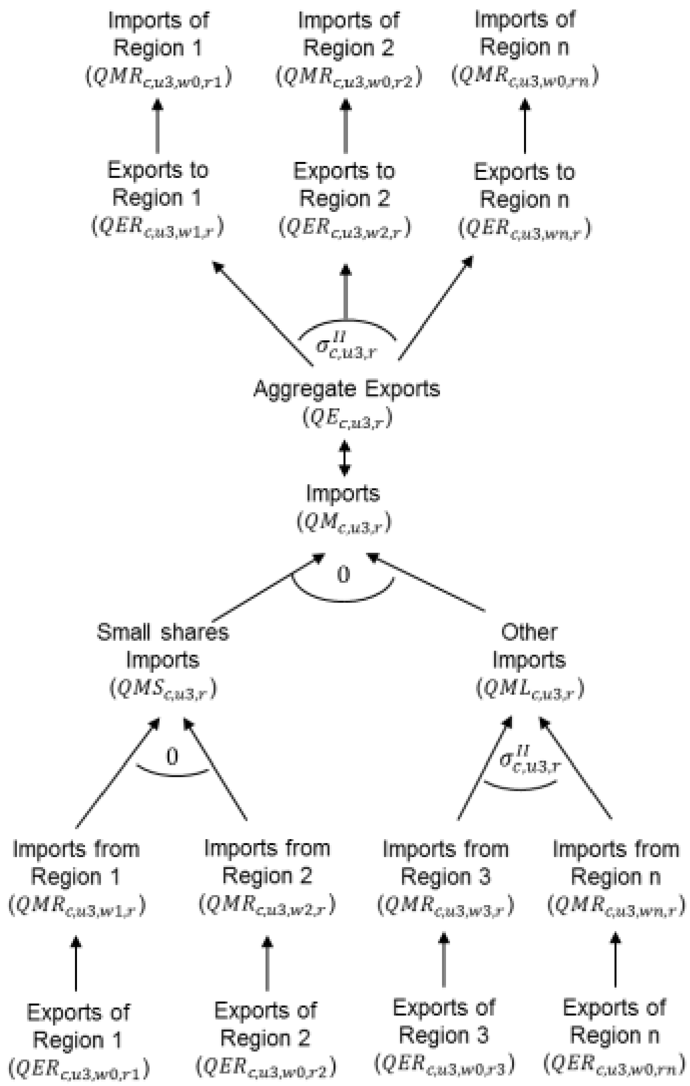
	Name	Equation	Number of Eq. and Var.	Variable	Globe Region
		Market Clearing Block: Globe			
(MC1.1)	$PTDEF_{c,u,r}$	$PT_{c,u,r} = PWE_{c,\text{uint},w,"glo"}$	(ct2*rgn)	$PT_{c,u,r}$	Yes
(MC1.2)	$GLOBEQUIL_{c,r}$	$\sum_{w,u} QT_{w,c,u,r} = \sum_{u\ and\ \forall\ map\_w\_r} QER_{c,u,w,"glo"}$	(ct2*rgn)		Yes

Figure 6. Price system for Globe region



Source: Authors' compilation based on McDonald et al. 2013.

Figure 7. Quantity system for Globe region



Source: Authors' compilation based on McDonald et al. 2013.

1.3.7 Market clearing

81. The model contains five regional markets: factor markets, commodity markets, and government, rest of the world accounts and capital accounts. The model contains several market clearing equations to make sure that supply equals demand or income equals expenditure for each region and for flows between regions.

82. There is no separate equilibrium condition for the supply of domestic output to the domestic market. In fact, activities are transformed to commodities and thus market clearing of domestic produced goods is achieved in equation P1.9. In the factor markets, factor supply of a specific type needs to equal aggregated factor demand of this factor type plus the stock of unemployed (Eq. MC2.1). This stock of unemployed factors is positive or zero (Eq. F3).

	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Market Clearing Block			
(MC2.1)	$FMEQUIL_{f,r}$	$FS_{f,r} = \sum_{a} FD_{f,a,r} + UNEMP_{f,r}$	(f*rgn)	$FS_{f,r}$	No
(MC2.2)	$QEQUIL_{c,u,r}$	$QQ_{c,"uint",r} = QINTD_{c,r}$	(c*1*rgn)	$QQ_{c,"uint",r}$	No
(MC2.3)	$QEQUIL2_{c,u,r}$	$QQ_{c,"uhhd",r} = QCD_{c,r}$	(c*1*rgn)	$QQ_{c,"uhhd",r}$	No
(MC2.4)	$QEQUIL3_{c,u,r}$	$QQ_{c,"ugov",r} = QGD_{c,r}$	(c*1*rgn)	$QQ_{c,"ugov",r}$	No
(MC2.5)	$QEQUIL4_{c,u,r}$	$QQ_{c,"ukap",r} = QINVD_{c,r}$	(c*1*rgn)	$QQ_{c,"ukap",r}$	No
(MC2.6)	$TRCONP_{w,c,u,r}$	$PWMFOB_{w,c,u,r} = PWE_{c,u,w,r} \ \forall \ map\_w\_r$	(cmr*u*w*r)	$PWMFOB_{w,c,u,r}$	Yes
(MC2.7)	$TRCONQ_{w,c,u,r}$	$QMR_{w,c,u,r} = QER_{c,u,w,r} \quad \forall \ map\_w\_r$	(cmr*u*w*r)	$QMR_{w,c,u,r}$	Yes
(MC2.8)	$COMTRADE_{c,u,r}$	$\sum_{w} (PWM_{w,c,uint,r} * QMR_{w,c,uint,r}) = \sum_{w} (PWE_{c,uint,w,r} * QER_{c,u,w,r}) + GLOBESLACK$	(1)	$GLOBESLACK$	Yes
(MC2.9)	$KAPGOVEQ_{r}$	$KAPGOV_{r} = YG_{r} - EG_{r}$	(rgn)	$KAPGOV_{r}$	No
(MC2.10)	$KAPREQUIL_{w,r}$	$KAPREG_{w,r} = \sum_{c,u} (PWMFOB_{w,c,u,r} * QMR_{w,c,u,r}) - \sum_{c,u} (PWE_{c,u,w,r} * QER_{c,u,w,r})$	(wgn*r)	$KAPREG_{w,r}$	Yes
(MC2.11)	$KAPREQUIL2_{w,r}$	$KAPREG_{w,r} = \sum_{c,u} (PT_{w,c,u,r} * QT_{w,c,u,r}) - \sum_{c,u} (PWE_{c,u,w,r} * QER_{c,u,w,r})$	(r)	$KAPREG_{w,r}$	Yes
(MC2.12)	$KAPEQUIL_{r}$	$KAPWOR_{r} = \sum_{w} KAPREG_{w,r}$	(r)	$KAPWOR_{r}$	Yes
(MC2.13)	$WALRASEQ_{r}$	$TOTSAV_{r} = INVEST_{r} + WALRAS_{r}$	(r)	$WALRAS_{r}$	Yes
(MC2.14)	$KAPEQUIL_{r}$	$KAPWORSYS = \sum_{r} KAPWOR_{r}$	(r)	$KAPWORSYS$	Yes

83. In the commodity markets, the domestic and import supply is equal to domestic demand of that commodity for intermediate, household, government or investment use (Eqs. MC2.2-MC2.5). The commodity trade accounts define the market clearing conditions for bilateral trade. The fob prices for imports ($PWMFOB_{w,c,r}$) for all imports by destination and source must be equal to the fob prices for exports ($PWE_{c,w,r}$) by source and destination (Eq. MC2.6). In addition the quantities of imports ($QMR_{w,c,r}$) for all imports by destination and source must be equal to the quantities of exports ($QER_{c,w,r}$) by source and destination (Eq. MC2.7). These equations are not completely straightforward since it is necessary in their implementation to employ mappings between exporting and importing regions that require the 'switching' of labels on accounts within the equation. Finally the commodity trade balance for Globe is defined (Eq. MC2.8), since this should be zero by definition a slack variable (*GLOBESLACK*) is attached. The trade

consistency equations do not however deal with the requirements for market clearing with respect to the trade transactions undertaken by the Globe region. However similar conditions apply for the margins trade (Eqs. MC1.1 and MC1.2).

84. Government savings ($KAPGOV_r$) clear the government accounts, which is the residual of government income and government expenditure (Eq. MC2.9). Similarly, the regional rest of world accounts clear with the bilateral balance of the regional capital account ($KAPREG_{w,r}$) being the residual of expenditures on imports and income from the partner region. The deficit/surplus on the current account is computed in two-stages. First the bilateral trade balances are calculated for the trade flows between regions other than Globe (Eq. MC2.10) and then for trade between Globe and all other regions (Eq. MC2.11) – the latter being the trade balances on margins trade. These transactions are valued in terms of the global numéraire. Then the overall balance of trade ($KAPWOR_r$) is computed for each region (Eq. MC2.12).

85. If all other accounts balance then so must the final account (Walras's law); thus the difference between savings and investment for all regions that save should always be zero and hence the slack variable $WALRAS_r$ should equal zero in equation MC2.13. That this variable equals zero is a good check on the correct specification of the model. Finally the global trade balance must by definition be zero and hence so must *KAPWORSYS* (Eq. MC2.14).

1.4 Model closure conditions[25,26]

86. In mathematical programming terms the model closure conditions are, at their simplest, a matter of ensuring that the numbers of equations and variables are consistent. However the economic theoretic dimensions of model closure rules are more complex, and, as would be expected in the context of an economic model, more important. The essence of model closure rules is that they define important and fundamental differences in perceptions of how an economic system operates (see Sen, 1963; Pyatt, 1987; Kilkenny and Robinson, 1990). The closure rules can be perceived as operating on two levels; on a general level whereby the closure rules relate to macroeconomic considerations, e.g., is investment expenditure determined by the volume of savings or exogenously, and on a specific level where the closure rules are used to capture particular features of an economic system, e.g. the degree of intersectoral capital mobility.

87. METRO allows for a range of both, general and specific, closure rules. The discussion below provides details of some of the options available with this formulation of the model by reference to the accounts to which the rules refer. However, as will become readily apparent there are many permutations available, and hence this discussion deals with the general principles rather than trying to define all possible permutations. The philosophy adopted in the implementation of this model is to define a (minimal) base closure for the replication of the base case and then impose closure changes within a loop in the experiment/simulation file. This approach allows substantial flexibility in the definition of policy simulations while simultaneously allowing sensitivity testing of the chosen model closures.

Absorption block

88. In order to allow for a 'balanced macroeconomic closure', with which it is possible to guard expenditure shares of the agents of the economy, METRO contains a series of equations which define absorption as well as non-household agents' expenditure shares (Eqs. MC3.1-MC3.3), which can be useful in setting up macro-economic closures. Absorption ($VFDOMD_r$) is the total value of final domestic demand including household, government demand and investment demand. Additionally, the model

25 This section is partly identical to McDonald et al. (2013) and Flaig (2014).

26 The term model 'closure' is used generically here to cover all permutations including variations in market clearing conditions and macroeconomic closure conditions.

contains a useful equation for calculation of GDP from value added (Eq. MC3.4). For households there exists no expression to guard expenditure shares, because household expenditure are defined after taxes and savings and it is difficult to justify setting the household shares relative to the value of total final demand since this would nullify the distributional consequences of a policy shock. If the expenditure shares by investment and government are fixed then the expenditure share of ALL households will by definition be fixed and $HEXP_r$ could be fixed for individual households if there was good reason.

	Name	Equation	Number of Eq and Var	Variable	Globe Reg.
		Market Clearing Block			
(MC3.1)	$VFDOMDEQ_r$	$VFDOMD_r = \sum_c \left[\sum_h \left(PCD_{c,r} * QCD_{c,h,r} * (1 + TV_{c,r}) \right) + PGD_{c,r} * QGD_{c,r} + PINVD_{c,r} * QINVD_{c,r} \right]$	(rgn)	$VFDOMD_r$	No
(MC3.2)	$INVESTSHEQ_r$	$INVESTSH_r * VFDOMD_r = INVEST_r$	(rgn)	$INVESTSH_r$	No
(MC3.3)	$VGDSHEQ_r$	$VGDSH_r * VFDOMD_r = \sum_c \left(PGD_{c,r} * QGD_{c,r} \right)$	(rgn)	$VGDSH_r$	No
(MC3.4)	$GDPEQ_r$	$GDP_r = \sum_{c,h} \left(PCD_{c,r} * QCD_{c,h,r} * (1 + TV_{c,r}) \right) + \sum_c \left(PGD_{c,r} * QGD_{c,r} \right) + \sum_c \left(PINVD_{c,r} * QINVD_{c,r} \right) + \sum_{c,u} \left(PE_{c,u,r} * QE_{c,u,r} \right) - \sum_{c,u} \left(PM_{c,u,r} * QM_{c,r} \right)$	(rgn)	GDP_r	No

Foreign Exchange Account Closure

89. For the world numéraire the exchange rate index for the reference regions (*EPRI*) is fixed, although a parameter, *numerchk*, is attached to allow for ease of checking the homogeneity of the model.[27] At the same time the exchange rate for Globe is fixed as equal to the world numéraire.

90. The current account can be defined either with a fixed exchange rate and a flexible current account balance, assuming an inflexible currency system, or the current account balance is fixed and the exchange rate floating, which is appropriate for countries, which, e.g., follow structural account programmes. Thus, there are clearly a range of permutations whereby the exchange rates for some regions are flexible while for others they are fixed.

27 In the base and model simulations, *numerchk* equals one. It is a parameter attached to the world numéraire and the regional numéraire. To check for homogeneity, a value other than one should have no effect on real variables in the model.

	Current Account Closure:		
	fix exchange rate index for reference regions and GLOBE	$ERPI = \overline{ERPI} * numerchk$	$ER_{glo} = \overline{ERPI} * numerchk$
	Fix current account balance, flexible exchange rates	$ER_{rgn} = \pm\infty$	$KAPWOR_{rgn} = \overline{KAPWOR_{rgn}}$
or	Fix exchange rate regime	$ER_r = \overline{ER_r}$	$KAPWOR_r = \pm\infty$
	World capital balance must be maintained		$KAPWORSYS = \overline{KAPWORSYS0} = 0$

Capital Account Closure

91. For the capital account closure, savings can either be investment driven or investment is savings driven. When investment is savings driven, hence, savings are to be fixed (neo-classical approach), all saving rates adjusters – additive and multiplicative – are fixed and investment free to adjust. Investment driven savings (Keynesian approach) can be achieved in several ways. On the investment side, either the value of investment (*$INVEST_r$*), the investment scaling factor (*$IADJ_r$*) or the share of investment in total final demand can be fixed (*$INVESTSH_r$*). If investment is fixed, the model needs to adjust by changes in the savings rate, and one of the saving rates adjusters are made flexible.

92. However there are potentially important interaction effects. Note that there are other sources of potential savings for region – the government and the trade balances. The magnitudes of these other savings sources can also be controlled through the closure rules (see below). Consequently there will clearly be an important interdependence between the choices of closure rules for different accounts; the most obvious one to be aware of is the interaction between household savings rates and household income tax rates when tax rates are made flexible and the level of government savings/deficit is fixed.

	Capital Account Closure:		
	Savings driven investment	Multiplicative Adjuster $SADJ_r = \overline{SADJ_r}$ Additive Adjuster $DSHH_r = \overline{DSHH_r}$	$IADJ_r = \pm\infty$ $INVEST_r = \pm\infty$ $INVESTSH_r = \pm\infty$
or	Investment driven savings	One savings rate adjuster (multiplicative or additive) becomes flexible, the other stays fixed.	One is fixed, two stay variable: $IADJ_{rgn} = \overline{IADJ_{rgn}}$ or $INVEST_r = \overline{INVEST_r}$ or $INVESTSH_r = \overline{INVESTSH_r}$

Government Account Closure

93. In the base specification for the government account, all tax rates are fixed, assuming government income to be ‘fixed’ and government savings variable. Base tax rates are defined as parameters, which can be adjusted with multiplicative and additive tax rate scaling factors, defined as variables. Thus, technically these scaling factors are fixed. Government expenditure is controlled by fixing the quantity of commodities demanded (*$QGDADJ_r$*), the value of government consumption expenditure (*EG_r*) or the share of government expenditure in the total value of domestic final demand (*$VGDSH_r$*). With this specification, all parameters, which the government can control, are fixed and the internal balance (government savings, *$KAPGOV_r$*) is free to adjust. If the government is assumed to maintain the internal balance, typically one of the tax rate adjusters becomes flexible.

94. The number of possible permutations for closing the government account for each region is substantial. Practical experience indicates that great care is needed when adjusting the government closure rules to avoid both unbalancing the model and imposing closure rules that are contradictory.[28]

	Government Account Closure:		
	Flexible internal balance	$TMADJ_r = \overline{TMADJ_r}$ $TMSADJ_r = \overline{TMSADJ_r}$ $TEADJ_r = \overline{TEADJ_r}$ $TSADJ_r = \overline{TSADJ_r}$ $TVADJ_r = \overline{TVADJ_r}$ $TXADJ_r = \overline{TXADJ_r}$ $TYFADJ_r = \overline{TYFADJ_r}$ $TYHADJ_r = \overline{TYHADJ_r}$ $TFADJ_r = \overline{TFADJ_r}$	One is fixed, two stay variable: $QGDADJ_r = \overline{QGDADJ_r}$ or $EG_r = \overline{EG_r}$ or $VGDSH_r = \overline{VGDSH_r}$
		$DTM_r = \overline{DTM_r}$ $DTMS_r = \overline{DTMS_r}$ $DTE_r = \overline{DTE_r}$ $DTS_r = \overline{DTS_r}$ $DTV_r = \overline{DTV_r}$ $DTX_r = \overline{DTX_r}$ $DTYF_r = \overline{DTYF_r}$ $DTYH_r = \overline{DTYH_r}$ $DTF_r = \overline{DTF_r}$	$KAPGOV_r = \pm\infty$
or	Fix internal Balance		$KAPGOV_r = \overline{KAPGOV_r}$
		Unfix **either** one of the tax rate adjusters	**or** one of the fixed government expenditure parameters.

95. Note also that as with the investment account, there is a needed care over setting the constraints on government demand. If the government demand volume adjuster ($QGDADJ_r$) is fixed, then the value of government expenditure might change due to changes in the prices of commodities ($PGD_{c,r}$). If the value of government expenditure (EG_r) is fixed then both government savings must be free to adjust as must the actual volume of expenditure, when tax rates are exogenous. The same applies if the shares of government expenditures in final demand ($VGDSH_r$) are fixed.

Technology and efficiency

96. The default assumption in the model is that efficiency, commonly called technology, is fixed. Hence the shift parameters are assumed to be constant. Changes in efficiency can either be imposed exogenously or a technology variable can be freed up so as to satisfy some other condition, e.g. the required efficiency gain needed to satisfy a predetermined increase in GDP.

Numéraire

97. The model specification allows for a choice between two price normalisation equations, the consumer price index (CPI_r) and a producer price index (PPI_r). A numéraire is needed for each region, to

28 The most common problems with contradictory government closure rules relate to the interactions between the government and capital (investment) accounts, in particular when a combination of flexible savings and tax rates producing mutually contradictory effects.

serve as a base since the model is homogenous of degree zero in prices for each region, and hence only defines relative prices.

	Technology and Efficiency		
	all fix	$ADX_r = \overline{ADX0_r}$ $ADVA_r = \overline{ADVA0_r}$ $ADFD_r = \overline{ADFD0_r}$	
or	one variable		
or	exogenous change		
	Numéraire Closure		
	Consumer price as numéraire	$CPI_r = \overline{CPI} * numerchk$	$PPI_r = \pm\infty$
or	Producer price as numéraire	$CPI_r = \pm\infty$	$PPI_r = \overline{PPI_r} * numerchk$

Factor market closure

98. There are several possibilities to specify factor markets for each region. Factors can be full employed and mobile or full employed and immobile across activities, factors can be unemployed or there are restrictions originating from factor demand. These specifications are determined by the interplay of factor supply ($FS_{f,r}$), factor prices ($WF_{f,r}$), sectoral proportions of factor prices ($WFDIST_{f,a,r}$) and factor demand ($FD_{f,a,r}$). Typically, for long term projections, factors are assumed mobile and full employed: then the factor price is flexible and factor supply fixed. For short term projections factors might become immobile across activities, i.e., capital, accordingly, factor demand is fixed. For this specification the sectoral factor price proportions need to adjust to clear the factor market. With fixed factor demand, the factor supply is also fixed, thus, the condition that fixes factor supply is now redundant and needs to be relaxed. To maintain the balance of equations and variables, at least one other condition must be imposed: this can be achieved by fixing the sectoral proportions for factor prices for a specific activity (*activ*) ($WFDIST_{f,activ,r}$), thus, activity specific returns will be defined relative to the return in *activ*. Unemployment can be introduced more sophisticated in the equation system with related variables and equations (Eq. U1) or simply via a specification of the factor market clearing. For this purpose, factor supply is set perfectly elastic and factor prices are fixed. In case factor supply might increase unrealistically in simulations, it is possible to include an upper bound on factor supply. Then the variable is not free anymore and the factor price of that factor needs to be unfixed. In another possible specification factor use by an activity might be restricted, for this purpose, factor demand of that activity is fixed ($FD_{f,activ,r}$) and the sectoral proportion of factor prices relating to this activity are unfixed ($WFDIST_{f,activ,r}$).

	Factor Account Closure:		
	Factors full employed and mobile	$FS_{f,r} = \overline{FS_{f,r}}$ $FD_{f,a,r} = \pm\infty$	$WF_{f,r} = \pm\infty$ [29] $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$
or	Factors full employed and immobile (implement for a single factor or all factors)	$FS_{f,r} = \pm\infty$ $FD_{f,a,r} = \overline{FD_{f,a,r}}$	$WF_{f,r} = \pm\infty$ $WFDIST_{f,a,r} = \pm\infty$ $WFDIST_{f,activ,r} = \overline{WFDIST_{f,activ,r}}$
or	Unemployment with perfectly elastic supply (implement for a single factor or all factors)	$FS_{f,r} = \pm\infty$ $FD_{f,a,r} = \pm\infty$	$WF_{f,r} = \overline{WF_{f,r}}$ $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$
or	Unemployment with restricted supply (implement for a single factor or all factors)	$FS_{f,r} \leq \overline{FS_{f,r}}$ $FD_{f,a,r} = \pm\infty$	$WF_{f,r} = \pm\infty$ $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$
or	Activity inspired restrictions on factor market closures (implement for single activities but not all factors)	$FS_{f,r} = \overline{FS_{f,r}}$ $FD_{f,a,r} = \pm\infty$ $FD_{f,activ,r} = \overline{FD_{f,activ,r}}$	$WF_{f,r} = \pm\infty$ $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$ $WFDIST_{f,activ,r} = \pm\infty$

2. THE METRO DATABASE

2.1 The METRO-SAM database v1

99. This section describes the METRO-Social Accounting Matrix (SAM) database and its construction. It derives from the GTAP V8.1L database (see Narayanan et al., 2012) and disaggregates trade flows based on use categories derived from OECD sources. The database is in SAM format and developed from a SAM version[30] of the underlying GTAP database. The original GTAP database distinguishes 57 sectors in GTAP classification and 129 regions with imports distributed proportionally across uses. The METRO-SAM is developed using detailed information from OECD sources, to distribute imports and taxes by source and uses and thus construct a SAM including the OECD Inter-Country Input-Output Model (OECD-ICIO, May 2013) information.

100. Hence, in the METRO-SAM database imports (and by default exports) are differentiated by 4 use categories:

1. intermediate use,
2. private consumption,
3. government consumption and
4. investment consumption.

[29] In GAMS the solver PATH, which is applied to solve the model, demands variables to be defined as free variables with a range between plus and minus infinity. However, the model specifications ensure that variables stay inside the economically meaningful range.

[30] See McDonald and Thierfelder (2004) for a detailed description of the SAM development.

101. In addition, we differentiate tariffs, export taxes, sales taxes and margins by use.[31] Accordingly, the commodity account identifies the use of imported and domestic goods. This split is based on new OECD data on use categories of imports and exports as opposed to the widely applied proportionality assumption.[32] The OECD-ICIO provides use information for all of the 44 GTAP agriculture and manufacturing sectors plus an additional 17 services sectors. The services data is mapped to attain the final 57 sectors available in the GTAP database. The 129 regions in GTAP are aggregated to match the 56 regions available in the OECD data[33]. Table 9 shows the structure of a regional SAM of the METRO-SAM database which distinguishes 56 regions, 57 sectors and 4 use-categories. Table 8 lists regions and sectors depicted in the METRO-database.

102. Similar to an Input-Output Table, a SAM is a transaction matrix in which each cell records transaction values between two specific agents identified by the row and column accounts. Income is depicted in rows and expenditures in the columns, e.g. private import consumption is displayed as expenditure of the household account and income to the commodity account. The focus of an IO-Table lies on the transactions concerning domestic production, its formation and use. The SAM approach goes beyond this and aims to incorporate all transactions in an economy at a given point in time, especially transactions between households, government and primary factors. The SAM methodology represents a complete characterization of the current account transactions of an economy as a circular system, and is completely embedded in the UN System of National Accounts.[34] Thus it is possible to follow income flows through the system and identify interrelationships between production, factors, government and households. As income of an account must equal expenditures, row and column totals must be identical. In the context of a global SAM, this translates to the trade relationships, where each export value of one region must have an identical counterpart in imports to another region or regions.

31 In version 1 of the METRO database tax and tariff rates remain the same across users but future development of the database will include differentiation of these accounts.

32 While the proportionality assumption was applied in the development of the OECD-ICIO, it was combined with additional detailed country and sector specific information which rendered the final statistics more robust.

33 See the Appendix for the sectors and regions mapping between GTAP and OECD-ICIO.

34 . http://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf

Table 8. List of countries and sectors in METRO database

Regions				Sectors			
ARG	Argentina	LTU	Lithuania	pdr	Paddy rice	ppp	Paper products, publishing
AUS	Australia	LUX	Luxembourg	wht	Wheat	p_c	Petroleum, coal products
AUT	Austria	LVA	Latvia	gro	Cereal grains nec	crp	Chemicals, rubber, plastic products
BEL	Belgium	MEX	Mexico	v_f	Vegetables, fruits, nuts	nmm	Mineral products nec
BGR	Bulgaria	MLT	Malta	osd	Oil seeds	i_s	Ferrous metals
BRA	Brazil	MYS	Malaysia	c_b	Sugar cane, sugar beet	nfm	Metals nec
CAN	Canada	NLD	Netherlands	pfb	Plant-based fibers	fmp	Metal products
CHE	Switzerland	NOR	Norway	ocr	Crops nec	mvh	Motor vehicles and parts
CHL	Chile	NZL	New Zealand	ctl	Cattle, sheep, goat, horse	otn	Transport equipment nec
CHN	China	PHL	Philippines	oap	Animal products nec	ele	Electronic equipment
CYP	Cyprus[a]	POL	Poland	rmk	Raw milk	ome	Machinery and equipment nec
CZE	Czech Republic	PRT	Portugal	wol	Wool, silk-worm cocoons	omf	Manufactures nec
DEU	Germany	ROU	Romania	frs	Forestry	ely	Electricity
DNK	Denmark	RUS	Russian Federation	fsh	Fishing	gdt	Gas manufacture and distribution
ESP	Spain	SAU	Saudi Arabia	coa	Coal	wtr	Water
EST	Estonia	SGP	Singapore	oil	Oil	cns	Construction
FIN	Finland	SVK	Slovakia	gas	Gas	trd	Trade
FRA	France	SVN	Slovenia	omn	Minerals nec	otp	Transport nec
GBR	United Kingdom	SWE	Sweden	cmt	Meat: cattle, sheep, goats, horses	wtp	Sea transport
GRC	Greece	THA	Thailand	omt	Meat products nec	atp	Air transport
HKG	Hong Kong, China	TUR	Turkey	vol	Vegetable oils and fats	cmn	Communication
HUN	Hungary	TWN	Chinese Taipei	mil	Dairy products	ofi	Financial services nec
IDN	Indonesia	USA	United States of America	pcr	Processed rice	ins	Insurance
IND	India	VNM	Viet Nam	sgr	Sugar	obs	Business services nec
IRL	Ireland	ZAF	South Africa	ofd	Food products nec	ros	Recreation and other services
ISR	Israel	ROW	Rest of World	b_t	Beverages and tobacco products	osg	PubAdmin, Defence, Health, Education
ITA	Italy	**additional in**		tex	Textiles	dwe	Dwellings
JPN	Japan	**LCR-version**		wap	Wearing apparel		
KHM	Cambodia	KAZ	Kazakhstan	lea	Leather products		
KOR	Korea	VEN	Venezuela	lum	Wood products		

Source: Authors' compilation.

a) Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus" issue.

b) Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Source: Authors' compilation.

Table 9. Structure of the METRO-SAM

	IMPORT COMMODITY	DOMESTIC COMMODITY	ACTIVITY	FACTORS	TARIFFS	EXPORT TAX	MARGINS	REST OF WORLD	HOUSHOLDS	SALES TAX	OTHER TAXES	GOVERNMENT	CAPITAL
IMPORT COMMODITY	0	0	Imported Intermediate Inputs	0	0	0	0	0	Private Import Consumption	0	0	Government Import Consumption	Investment Import Consumption
DOMESTIC COMMODITY	0	0	Domestic Intermediate Inputs	0	0	0	0	Exports of Commodities	Private Domestic Consumption	0	0	Government Domestic Consumption	Investment Domestic Consumption
ACTIVITY	0	Domestic Supply	0	0	0	0	0	0	0	0	0	0	0
FACTORS	0	0	Expenditure on Primary Inputs	0	0	0	0	0	0	0	0	0	0
TARIFFS	Bilateral Import Tariffs by Use Category	0	0	0	0	0	0	0	0	0	0	0	0
EXPORT TAX	0	Bilateral Export Taxes by Use Category	0	0	0	0	0	0	0	0	0	0	0
MARGINS	Trade and Transport Margins by Use	0	0	0	0	0	0	0	0	0	0	0	0
REST OF WORLD	Bilateral Imports by Use Category	0	0	0	0	0	Imports of Trade and Transport Margins	0	0	0	0	0	0
HOUSEHOLDS	0	0	0	Distribution of Factor Incomes	0	0	0	0	0	0	0	0	0
SALES TAX	Sales Taxes on Imports by Use Category	Domestic Sales Taxes by Use Category	0	0	0	0	0	0	0	0	0	0	0
OTHER TAXES	0	0	Taxes on production and Factor Use	0	0	0	0	0	Direct/ Income tax	0	0	0	0
GOVERNMENT	0	0	0	0	Tariff Income	Export Tax Income	0	0	0	Sales Tax Income	Other Tax Income	0	0
CAPITAL	0	0	0	Depreciation / Allowances	0	0	0	Foreign Savings	Household Savings	0	0	Government Savings	0

Source: Author's compilation.

103. The first two rows of Table 9 show the use of commodities by the four use categories, distinguishing imported and domestic commodities. The producing units, so-called activities, use domestic and imported commodities as intermediate inputs. Households, the government and the capital account use commodities for private, government and investment consumption, respectively.

104. Exports are displayed as purchases by the rest of the world of domestic commodities only. There are no direct re-exports, the cell with import commodities in the row and rest of world in the column is therefore empty. The consumption values of imports, in the first column, include bilateral imports from the rest of the world, bilateral trade and transport margins, bilateral import tariffs and sales taxes, each distinguished by the respective use category.

105. The total value of domestic commodity supply includes the domestic supply at producer prices, supplied by the activity account, sales taxes and export taxes, each distinguished by the respective use category. Activities purchase intermediate and primary inputs, and pay taxes on production and factors. The production is supplied to the domestic commodity accounts.

106. Households receive income from factors and spend it on consumption of goods, income tax and save the residual. The government receives income from the various tax instruments and spends this income on consumption and savings. The capital account receives income from savings, deducting or including depreciation/allowances, and spends it on capital goods consumption.

107. The dimensions of the SAM are determined by the number of accounts within each of its cells. As mentioned above, the base data of this version contains detailed information on 56 regions, 57 sectors, 4 use-categories and 8 primary factors. Table 10 shows the dimensions of the METRO-SAM database version 1 with a total of 1 540 accounts for each regional matrix. Given the large number of accounts in each region’s SAM and the relative large number of regions this renders the total number of transaction values in the full database very large, 2.4 Million, even when considering empty cells.

Table 10. Dimensions of the METRO-SAM database version 1

Account Groups	Number of accounts	
Commodities	(2*c)	114
Activities	(a)	57
Factors	(f)	8
Taxes	(2*r*u+1*f+1*u+2)	462
Other domestic institutions	3	3
Margins	(3*r*u)	672
Trade	(r*u)	224
Total number of accounts		1 540
Number of data points in global SAM		2 352 913

Source: Authors’ compilation.

108. When the database is large, the size of the model which uses this database must even be larger because each transaction flow is at least connected to two variables: a price and a quantity. The use of a large model is problematic, first, in solver capacity and can be quite unhandy regarding solution time and output. Second, a large model makes results interpretation unnecessary complex. CGE models are therefore generally applied with aggregate databases which are designed for the specific study purpose. In

this regard, the size of the base data is important to provide a reasonable choice of aggregations for the user. Hence, the aggregation of the database is highly recommended for the application of METRO[35].

2.2 Construction of the METRO-SAM database v1

109. The METRO-SAM database v1 is based on an augmented SAM version of the GTAP database (McDonald and Thierfelder, 2004), its construction follows three steps: first, use shares for commodity imports (and exports) are generated which are used to split the trade matrices. Based on this split the SAM is rearranged into the new METRO-SAM format in a second step. Final corrections to achieve a balanced SAM are made in a third step.

Generating a full dataset of use shares

110. The use shares which are used to split trade flows by use category (intermediate, household, government and investment consumption) are based on two data files which originate from data underlying the OECD-ICIO tables. The shares are derived applying a set of conversion keys that have been estimated using classification correspondence tables, developed internally by the OECD Directorate for Science Technology and Industry, and available classification correspondence tables published by the UN statistical division (UNSD)[36].

- Data on *manufacturing and agricultural sectors* was supplied with bilateral import and export market shares, available for 63 regions, with the aggregate ROW only as partner country, 44 GTAP sectors and 5 use categories. As both, import and export shares, are available, import shares are chosen to serve as base data, as the quality of import data generally tends to be better than export data. For the ROW region export shares are used to complete the dataset.

- Bilateral export shares for *services sectors* are available for 58 regions, 17 OECD-ICIO sectors, which correspond to 9 aggregate GTAP sectors, and 4 use categories.

111. The data sources differ from the intended (GTAP) format and between each other in:

- Country coverage: The base SAM database identifies 129 regions, compared to 63 and 58 regions in the manufacturing/agricultural and services use-shares data, respectively. The use shares are applied to the 56 regions which are identified in all three databases. For other regions, where no use shares are available, we assume proportionality across uses. (Annex Table A2).

- Sector classification: The base SAM distinguishes 57 GTAP sectors, while use shares for manufacturing and agriculture are provided in GTAP format for 44 sectors. Sectors 1 to 42 are applied directly while GTAP 43 and GTAP 44 are services sectors thus the OECD services use shares are applied to these two sectors. Services use shares are provided for 9 aggregate GTAP services sectors which are mapped according to the services sector concordance (Annex Table A1). After the split the database is aggregated to represent the country coverage where use shares from OECD sources are available.

- Use categories: The services use-shares are provided in the final 4 use categories of interest: (1) intermediate use, (2) private consumption, (3) government consumption and (4) investment

35 An aggregation of 11 commodities and sectors and 18 regions still has over 1.6 million of variables to be analysed.

36 The BDTIxE documentation provides the details of the split process. Also see http://www.oecd.org/sti/ind/49894138.pdf.

consumption. Manufacturing/agricultural use-shares are provided in 5 use categories: intermediate use, household consumption, capital goods, mixed use and miscellaneous use. Household consumption contains both, private and government consumption, hence, the shares are distributed proportionally over these two use categories. The mixed and miscellaneous uses, which account for about 10% of total trade flows, are singled out because this category contains data on all four use categories. The mixed use category includes items like personal computers, passenger cars, personal phones, precious goods and packed medicines, other mixed uses are assigned to miscellaneous uses. As it is not possible to allocate them to one of the other categories, they are distributed evenly among the other categories.

112. Finally there are cases where the GTAP database provides information on trade flows where no use-shares are available, e.g. the GTAP database report imports of paddy rice from Australia to China, but OECD data does not provide use shares for this particular trade flow. These missing bilateral use-shares are imputed assuming proportionality across uses. About 30% of all use-shares in the final 56 regions are imputed.

Rearranging the SAM

113. The complete set of use-shares is applied to split the trade flows by use. Thus, the import and export matrices become 4 dimensional, reflecting bilateral trade flows by commodity and use category. Thus in the original database, it was possible to report imports by sector and country partners, it is now possible to track imports by commodity (e.g. rice) and source (e.g. India) to destination (e.g. Saudi Arabia) and use (e.g. household consumption). In addition to the trade accounts, the relevant tax accounts are split, too, assuming equal rates over use categories for import tariffs, export taxes and sales taxes.[37] Trade and transport margins are assumed same for all use categories.

114. The identification of imports as well as the relevant taxes and margins by use category allows defining imported commodity demand by use, valued at purchaser price. The import demand value is deducted from the original composite commodity demand to arrive at the domestic commodity demand.

Correction of anomalous entries

115. Import demand by use is defined by the OECD shares data, which are applied to the GTAP data based SAM. The total sum of imports over all uses stays the same, but the distribution of imports over uses is a new feature. The merger of the two different datasets, which do not necessarily perfectly fit to each other, can raise certain data anomalies. For example, there are several cases where the distribution of imports among uses according to the OECD shares imply total values different from those reported in the GTAP based SAM, leading to the import demand allocated to a specific use category being larger than the composite demand, i.e., imported and domestic demand, in that use category. For example, use-shares imply a value of rice imports by households in Saudi Arabia to be greater than the original composite rice demand, therefore implying a negative value for domestic rice demand. In order to correct for these erroneous entries, the use-shares are adjusted to meet the overall constraints of the underlying SAM database. This approach is chosen to keep the adjustment process solely within the new information introduced while maintaining the integrity of the underlying SAM.

116. First, for those entries showing anomalous outcomes (about 7% of total use entries in the new database) imports are redistributed over uses. A maximum import by use category is set to 95% of the composite (domestic and imported) consumption in a use category. If the import share over all uses is

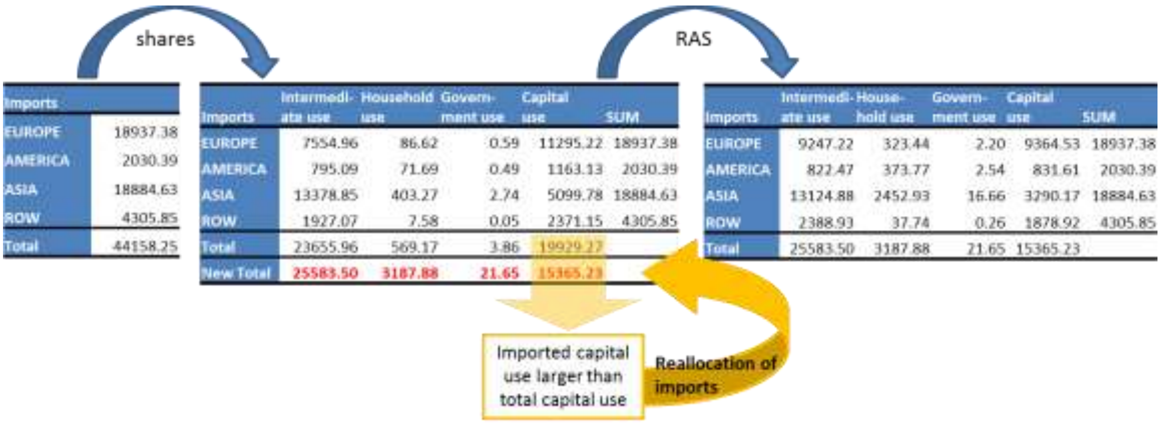
37 Currently tax and tariff rates remain the same across users but future development of the database will include differentiation of these accounts.

larger than 95% of total consumption, the maximum import is set to the full value of composite consumption in a use category. Hence, if the originally allocated import demand is larger than the import maximum, the surplus imports are redistributed over the other uses in an iterative approach. In a first step redistribution occurs between households and government, and between intermediates and capital. Thus we recognize the closer relation of final consumption of government and households as well as intermediate inputs and investment consumption, which is also reflected in the creation of the use-shares. In a second step the still remaining surplus is redistributed proportionally over all uses and finally, in a third step, additionally over uses.

117. Second, bilateral use shares are then adjusted to the redistributed values of imports by use. For this purpose, the relevant import matrices for a specific country and commodity by use category and partner country are balanced. Figure 8 displays the process as numerical example for Russian motor vehicles imports, for reasons of display, regions are aggregated to 4. The table on the left side shows the original trade flows in the GTAP/GLOBE database. OECD-use shares are applied and transform the import vector into a matrix. In case there are anomalous entries, in Figure 8 this is displayed as a negative domestic use of capital goods, imports are reallocated among uses as described in the previous paragraph. The reallocation leaves the import matrix with new column totals while maintaining the row sums. The matrix is rebalanced applying the RAS matrix balancing method and finally the right table on Figure 8 shows the import matrix containing the new use shares. In this procedure we balance a series of matrices where row and column sums are known and coefficients need to adjust. For this kind of problems the RAS methodology is most appropriate and therefore applied (Robinson et al. 2001). In cases where RAS cannot solve, because the difference between initial and final distribution are too large, i.e. because of zeroes, the initial distribution is adjusted.

118. Imputed shares account for about 30% of total shares data. 6% of all use shares are adjusted in the previously described process, of which in two thirds of the cases (or about 4% of all entries) the adjustments of the bilateral use shares are larger than 5 percentage points.

Figure 8. Adjustment process for anomalous entries, example for Russian motor vehicles imports



Imports	
EUROPE	18937.38
AMERICA	2030.39
ASIA	18884.63
ROW	4305.85
Total	44158.25

Imports	Intermediate use	Household use	Government use	Capital use	SUM
EUROPE	7554.96	86.62	0.59	11295.22	18937.38
AMERICA	795.09	71.69	0.49	1163.13	2030.39
ASIA	13378.85	403.27	2.74	5099.78	18884.63
ROW	1927.07	7.58	0.05	2371.15	4305.85
Total	23655.96	569.17	3.86	19929.27	
New Total	25583.50	3187.88	21.65	15365.23	

Imports	Intermediate use	Household use	Government use	Capital use	SUM
EUROPE	9247.22	323.44	2.20	9364.53	18937.38
AMERICA	822.47	373.77	2.54	831.61	2030.39
ASIA	13124.88	2452.93	16.66	3290.17	18884.63
ROW	2388.93	37.74	0.26	1878.92	4305.85
Total	25583.50	3187.88	21.65	15365.23	

Source: Authors' compilation.

2.3 Elasticities

119. In addition to the SAM database METRO employs a set of elasticities which govern the responses in behavioural relationships, Table 11 lists the relevant elasticities and its related sources.

120. Four elasticities relate to trade: these are the first and second level substitution elasticities on each, the import and the export side. As general rule the second level elasticity is typically larger than the first

level elasticity. The user can choose to take trade elasticities from the GTAP database, which are based on academic literature. Given their importance there have been a number of studies estimating trade elasticity parameters.[38] Despite these studies, there remains little consensus as to what the 'right' values are, especially in the context of CGE modelling. The problem is that measuring the sensitivity of demand to changes in relative (import) prices, becomes bogged down in several practical issues. Furthermore, the GTAP database provides elasticities on the import side only and as no other estimates are available these are applied on the export side, too. Alternatively each trade elasticity can be provided by the user.

121. The model employs a three level nested CES production process, accordingly there are three substitution elasticities related to the production process. At the first level the production elasticity (σ_x) governs substitution between aggregate intermediates and aggregate value added. At the second level, the value added elasticity (σ_{va}) is employed and substitution between labour categories forming aggregate labour is governed on the third level by the labour elasticity (σ_{fd}). Elasticities should be user defined but for the first two levels can be chosen from GTAP, too.

122. Household demand employs two elasticities, first the frisch parameter sets the minimum consumption level used in the Stone-Geary utility function. Second, the income elasticity defines demand changes related to income changes. Both, the frisch parameter and the income elasticity are defined by the user.

123. The elasticities provided, i.e. export elasticities and the elasticities related to production and household demand, are considered only a starting value or place holder and are by no means considered final. Hence, elasticities should be adjusted according to study purpose and aggregations.

124. As most of the elasticities employed are not based on strong empirical estimates it is advisable to always test the sensitivity of model results to changes in elasticities with a comprehensive sensitivity analysis.

Table 11. List of elasticities used in METRO

Elasticity		Source
Trade		
CES first level import	σ^{I} Figure 2	GTAP or user defined
CES second level import	σ^{II} Figure 2	GTAP or user defined
CET first level export	Ω^{I} Figure 2	GTAP import or user defined
CET second level export	Ω^{II} Figure 2	GTAP import or user defined
Production		
CES level 1: production	σ_x Figure 4	GTAP or user defined
CES level 2: value added	σ_{va} Figure 4	GTAP or user defined
CES level 3: labour	σ_{fd} Figure 4	user defined
Household demand		
Frisch parameter		User defined
Income		User defined

Source: Authors' compilation.

38. See Goldstein and Khan (1985) and McDaniel and Balistreri (2003) for reviews of the literature.

3. MODULES

125. The modules are alternative policy instruments or model variations which each can be included if they meet the study purpose. However, it is important to consider that each module adds complexity to the model framework. In order to easily control the model complexity the modular approach is chosen. Thus, each module can easily be switched on and off in the file 'METRO_controls.inc' by commenting in or out the corresponding line. In addition, the modules are modelled fully in separate include files so relevant equations, variables, parameters and its calibration can easily be accessed.

126. Currently there are 3 modules available: the LCR module supplies a policy instrument to depict local content requirements (LCR) in form of quantitative restrictions. The alternate intermediate nesting identifies activity specific imports and domestic supply and the price preference module allows the depiction of policies where sales taxes are differentiated between imported and domestic commodities, such as a tax break on domestically sourced commodities.

3.1 Local content requirement (LCR) Module

127. Studies of local content requirements (LCR), to date, have relied on analysing their impact through their effect on prices. They are usually converted to *ad valorem* equivalents or treated as shadow prices. For example, Jensen and Tarr (2008), in a recent attempt to measure LCR impacts, examined the oil and gas sector in Kazakhstan. They represent the Kazakh local content policies as a 20% price preference (subsidy) by multinationals for domestic inputs, which is financed out of the gross revenues of multinational oil firms. They find that the elimination of these local content policies results in a gain in welfare equal to 0.2% of consumption.

128. The use of *ad valorem* equivalents in the context of LCRs suffers from two major problems: first, there are no estimates of the size of a possible ad valorem equivalent. Accordingly, e.g., Hufbauer, et al., (2013) simply apply an ad valorem equivalent of 10%. Second, as noted above, LCRs use quantities rather than prices to influence the geographic distribution of purchases, hence, LCRs are not price instruments. Rather they affect the quantity and through quantity they influence prices. This implies different market adjustment processes. To estimate effects of these policies we develop an approach based on quantity effects to include LCRs in a CGE framework.

129. Many LCRs are defined as a percentage share of base supply and are assumed to affect imports only when local content is beneath that share, making the specific LCR binding. The underlying assumption is that the company's observed intermediate input use is based on optimal allocation at given prices. It will change this input allocation only if prices change or it is required to because of the LCR policy. As long as a company is already fulfilling the LCR, it is not binding. For example, if the current domestic content in inputs is 60% and the relating LCR is 50%, there will be no need to adjust the composition of imported and domestically produced intermediate inputs. When the LCR becomes binding – for example if the current domestic content in inputs is 40% and the relating LCR is 50% – the company must reduce its imports use and increase inputs sourced from domestic production to a minimum of 50%.

130. To capture this reality of LCR policy, domestically produced supply (*QD*) is modelled in two components (Eq. LCR-M1); Figure 9 displays the structure of the LCR module. The first component is the quantity which would be supplied without the LCR (QD^{NL}) (in the base situation the 40% in the example). The second component is the quantity which is additionally needed to fulfil the LCR (QD^{LCR}) (10%).

$$QD = QD^{LCR} + QD^{NL} \qquad \text{(LCR-M1)}$$

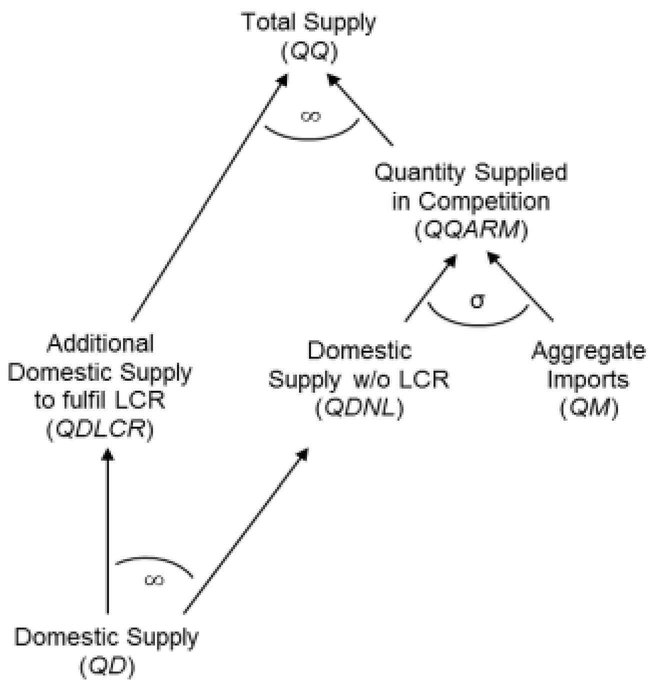
131. As noted above if domestic sources meet or surpass the LCR, $QD = QD^{NL}$.

132. Total supply is likewise broken into two components (Eq. LCR-M2), the quantity which is supplied through competition (QQ^{ARM}) between imports (*QM*) and domestically produced commodities, and the additional quantity of domestic supply to fulfil the LCR.

$$QQ = QD^{LCR} + QQ^{ARM} \qquad \text{(LCR-M2)}$$

133. The share going to fill the LCR is cut out prior to the Armington function, because this part of the domestic supply must be supplied domestically irrespective of the relative prices and thus is not in competition to imports. If an LCR is binding, a part of total supply is now supplied through the LCR channel, which decreases the demand of goods supplied through the Armington nest. Relative prices adjust leading to changes in the mix of competitively supplied imports and domestic quantities. As the competitive domestic supply and total supply are subject to change, the additional LCR quantity is also variable and defines the additional domestic supply necessary to fulfil the LCR in the new equilibrium.

Figure 9. The local content requirements module



Source: Authors' compilation.

134. The Armington equation (Eq. LCR-M3) gives the total supply (from imports and domestic sources) under a competitive market. It is an aggregate of the domestic production that is supplied without the LCR *(*QD^{NL}) and aggregate imports (*QM*), where δ is a share parameter, ρ the elasticity parameter and α a shift parameter.

$$\mathrm{QQARM}_{c,r} = \alpha * \left[\delta * \mathrm{QM}^{-\rho} + (1-\delta) * \mathrm{QD}^{\mathrm{NL}^{-\rho}}\right]^{-1/\rho} \qquad \text{(LCR-M3)}$$

135. The optimal combination of imports and domestic supply is determined by the first order condition to minimise costs and depends on the relative prices of imports (*PM*) to domestic commodities (*PD*). Domestic supplied commodities are assumed homogeneous, irrespective of the channel through which they are supplied.

$$\mathrm{QM} = \mathrm{QD}^{\mathrm{NL}} * \left[\frac{\mathrm{PD}}{\mathrm{PM}} * \frac{\delta}{1-\delta}\right]^{1/(1+\rho)} \quad \text{(LCR-M4)}$$

136. The quantity of local content required (*QLCR*) is defined as the share (*lcrsh*) of the total supply in the base ($\overline{QQ}$). Where *lcrsh* is defined as the share of total supply which must be of local content and thus constitutes the policy parameter (Eq. LCR-M5).

$$QLCR = \overline{QQ} * lcrsh \quad \text{(LCR-M5)}$$

137. The LCR is implemented as mixed complimentary problem (MCP), with a regime switch between the situation where the LCR is not binding and the situation where it becomes binding. When the LCR is binding, the market itself does not supply the required domestic production (through the market via the 'normal' Armington function, QD^{NL}), and an additional domestic quantity needs to be supplied to fulfil the LCR which is QD^{LCR}. The quantity supplied domestically (*QD*) must always be greater or equal the quantity of local content required (*QLCR*) (Eq. LCR-M6), hence the slack variable (*s*) is by definition negative or zero (Eq. LCR-M7). The slack variable reports the amount of domestic supplied quantity which is supplied in surplus to the LCR.

$$s = QLCR - QD \quad \text{(LCR-M6)}$$

and

$$s \leq 0 \; with \;\; QD^{LCR} \geq 0 \quad \text{(LCR-M7)}$$

3.2 Alternate intermediate nesting

3.2.1 Activity specific demand

138. The alternate intermediate nesting identifies activity specific imports and domestic supply. This feature is used first (and immediately), for the modelling of local content requirements (LCRs) which are typically targeted on the imported input use of an activity and not on all imports of a commodity. Second, the nesting can be used to track global value chains (GVCs).

139. In the base model, imports and domestic supply are first aggregated and then composite intermediate inputs are distributed over activities. The alternate intermediate nesting shifts the Armington equation, which combines imports and domestic supply, one level up and locates it directly at the activity specific demand for intermediate inputs.

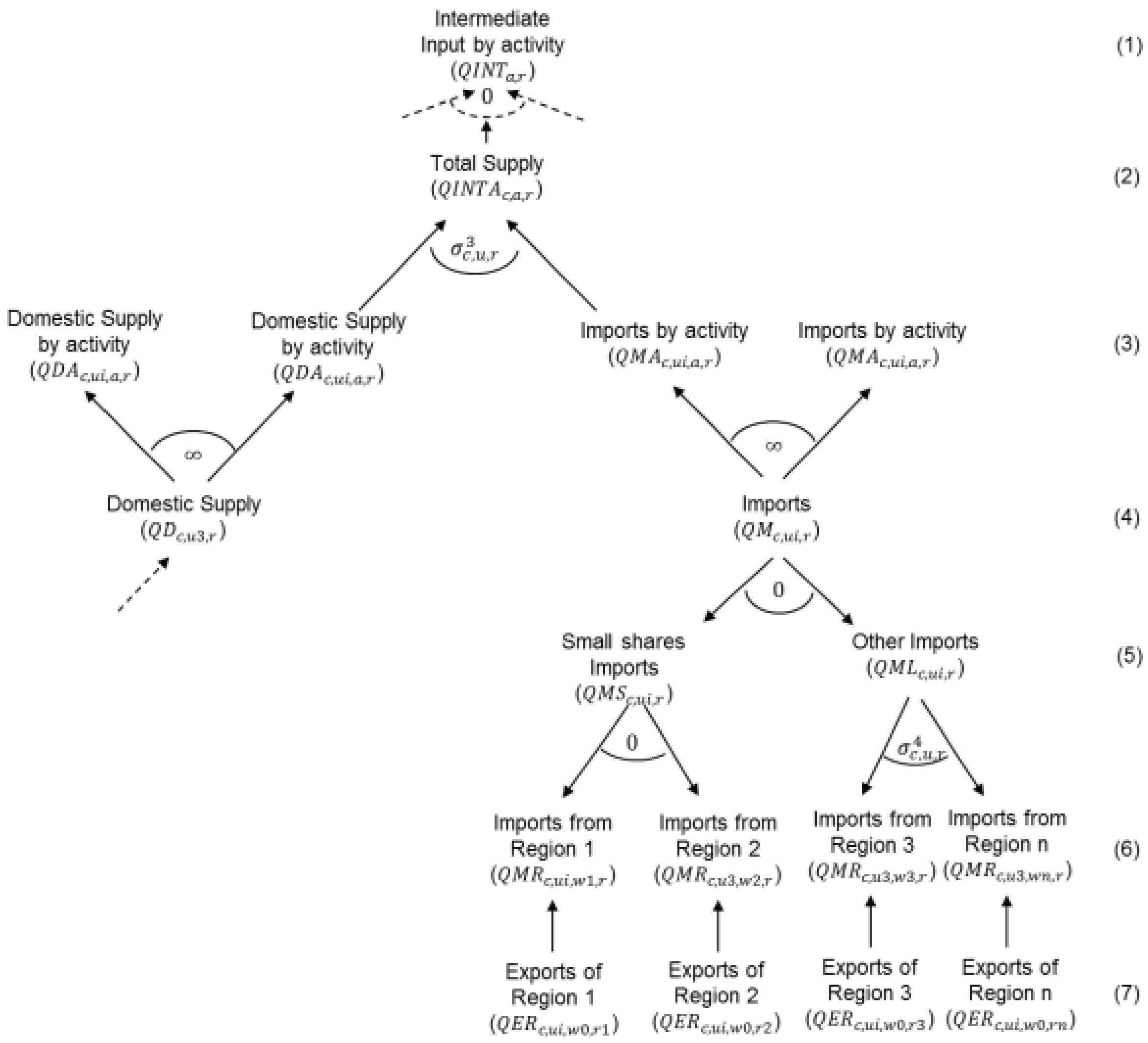
140. Figure 10 shows the relation between quantities and Figure 11 between prices. Following the import branch on the lower right of Figure 10, similar to the base model and other use categories, bilateral imports of commodities *c* for intermediate use *ui* by region *r* are aggregated distinguishing small share imports (Levels 7-4 in Figures 10 and 11). Aggregate imports ($QM_{c,ui,r}$) are then split by activity a ($QMA_{c,ui,a,r}$) (Level 3) applying information from the base data. We maintain the implicit assumption from the base model and assume perfect substitutability between the activities (Eqs. INT-M1 and INT-M2), hence the import price ($PM_{c,ui,r}$) and the activity specific import price ($PMA_{c,ui,a,r}$) are equal[39] (Figure 11).

$$QM_{c,ui,r} = \sum_a QMA_{c,ui,a,r} \quad \text{(INT-M1)}$$

$$PM_{c,ui,r} = PMA_{c,ui,a,r} \quad \text{(INT-M2)}$$

39 This assumption can easily been dropped when additional information or new evidence suggests so.

Figure 10. Alternate intermediate input nesting – quantities



Source: Authors' compilation.

141. In the domestic branch, at the left of Figures 10 and 11, domestic supply is split by activity similar to the imports branch.

$$QD_{c,ui,r} = \sum_a QDA_{c,ui,a,r} \quad \text{(INT-M3)}$$

$$PD_{c,ui,r} = PDA_{c,ui,a,r} \quad \text{(INT-M4)}$$

With $QD_{c,ui,r}$ being domestic supply, $QDA_{c,ui,a,r}$ the domestic supply by activity, $PD_{c,ui,r}$ the price for domestic supply and $PDA_{c,ui,a,r}$ the activity specific price for domestic supply.

142. Activity specific imports and activity specific domestic supply are aggregated with the Armington equation forming an aggregate activity and commodity specific intermediate input supply ($QINTA_{c,a,r}$).[40]

[40] As *ui* consists only of one use category this dimension can simply be dropped.

$$QINTA_{c,a,r} = ac_{a_{c,ui,a,r}} * \left(delta_{a_{c,ui,a,r}} * QMA_{c,ui,a,r}^{-rhoc_{c,u,r}} + \left(1 - delta_{a_{c,ui,a,r}}\right) * QDA_{c,ui,a,r}^{-rhoc_{c,u,r}}\right)^{-1/rhoc_{c,u,r}} \quad \text{(INT-M5)}$$

With: $ac\_a_{c,ui,a,r}$ is the shift parameter, $delta\_a_{c,ui,a,r}$ the share parameter and $rhoc_{c,u,r}$ the elasticity parameter for the Armington CES-function.

143. The optimal ratio of imports and domestic supply is determined by the first order condition.

$$QMA_{c,ui,a,r} = QDA_{c,ui,a,r} \left(\frac{PDA_{c,ui,a,r}}{PMA_{c,ui,a,r}} * \frac{delta\_a_{c,ui,a,r}}{(1-delta\_a_{c,ui,a,r})}\right)^{\frac{1}{1+rhoc_{c,ui,r}}} \quad \text{(INT-M6)}$$

144. The basic supply price ($PINTS_{c,ui,a,r}$) is the weighted average of import and domestic supply prices.

$$PINTS_{c,ui,a,r} * QINTA_{c,a,r} = PDA_{c,ui,a,r} * QDA_{c,ui,a,r} + PMA_{c,ui,a,r} * QMA_{c,ui,a,r} \quad \text{(INT-M7)}$$

145. The purchaser price of intermediate inputs ($PINTA_{c,a,r}$) includes the sales tax rate ($tsa_{c,ui,a,r}$).[41]

$$PINTA_{c,a,r} = PINTS_{c,ui,a,r} * \left(1 + tsa_{c,ui,a,r}\right) \quad \text{(INT-M8)}$$

146. Finally, on level 1 of Figure 10, activities use intermediate input commodities in fixed shares.

$$PINT_{a,r} = \sum_c \left(ioqint_{c,a,r} * PINTA_{c,a,r}\right) \quad \text{(INT-M9)}$$

$$QINTA_{c,a,r} = ioqint_{c,a,r} * QINT_{a,r} \quad \text{(INT-M10)}$$

With $ioqint_{c,a,r}$being the intermediate input output coefficients.

147. Unused variables, those which are replaced by new variables that are indexed over activities, are set to zero. These are the supply price of composite intermediate input commodities ($PQS_{c,ui,r}$), the consumer prices ($PQD_{c,ui,r}$, $PINTD_{c,ui,r}$) and intermediate input demand ($QINTD_{c,r}$).

148. The tax revenue ($STAX_r$) equation is extended to include the sales tax revenue from intermediate input use. [42]

$$STAX_r = \sum_{c,u}\left(TS_{c,u,r} * PQS_{c,u,r} * QQ_{c,u,r}\right) + \sum_{c,ui,a}\left(tsa_{c,ui,a,r} * PINTS_{c,ui,a,r} * QINTA_{c,a,r}\right) \quad \text{(INT-M11)}$$

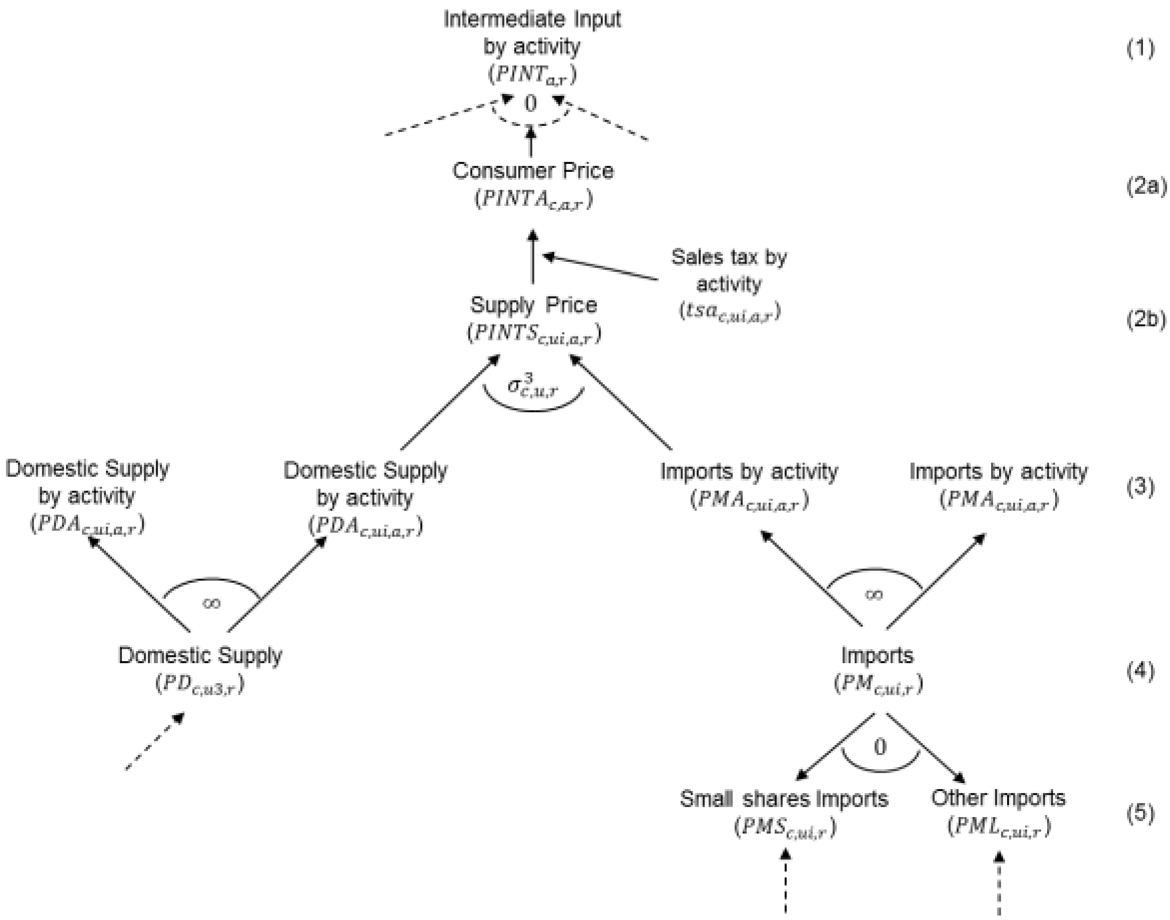
149. Total supply of intermediate inputs ($QQ_{c,ui,r}$) is calculated for the analysis of aggregate intermediate input supply by commodity.

$$QQ_{c,ui,r} = \sum_a QINTA_{c,a,r} \quad \text{(INT-M12)}$$

41 Unlike the depiction of other tax rates in the model, the sales tax rate is a parameter in this version.

42 Again, set *ui* has only one member and thus can be dropped in equation INT-M11. Unused variables are set to zero; therefore $PQS_{c,u,r}$ for *ui* is zero and the intermediate input tax revenue is not included in the first sum.

Figure 11. Alternate intermediate input nesting – prices



Source: Authors' compilation.

3.2.2 Activity and commodity specific local content requirement module

150. The alternate intermediate input nesting identifies domestic supply and imports by commodity and activity. This makes it possible to model activity and commodity specific LCRs, such as imports of coal used in the electricity sector. The activity and commodity specific LCR module (Figure 12) is inserted on the domestic supply by activity on the domestic branch between Levels 2 and 3 in Figure 10.

151. The structure of the module is similar to the commodity specific LCR-module described above, but extended with an activity dimension. As intermediate input use is the only use category which is activity specific, the use dimension can be omitted. The activity specific local content requirement share ($lcrsh\_A_{c,a,r}$) is zero in the base situation and is the policy instrument which can be shocked in simulations.

$$QLCR\_A_{c,ui,a,r} = QINTA0_{c,a,r} * lcrsh\_A_{c,a,r} \quad \text{(INT-M13)}$$

$$SLACK\_A_{c,ui,a,r} = QLCR\_A_{c,ui,a,r} - QDA_{c,ui,a,r} \quad \text{(INT-M14)}$$

$$QINTA_{c,a,r} = QDLCR\_A_{c,ui,a,r} - QQARM\_A_{c,ui,a,r} \quad \text{(INT-M15)}$$

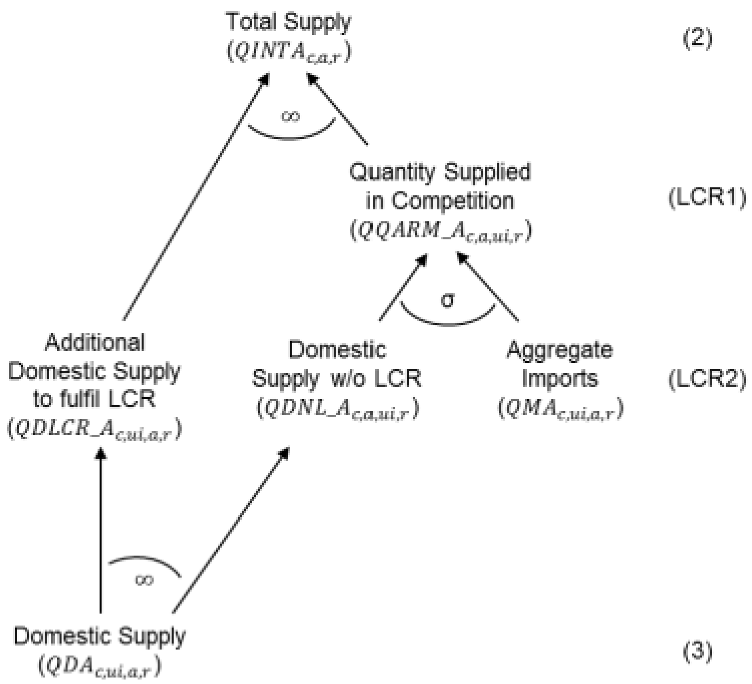
$$QDA_{c,ui,a,r} = QDNL\_A_{c,ui,a,r} - QDLCR\_A_{c,ui,a,r} \qquad \text{(INT-M16)}$$

$$0 \geq SLACK\_A_{c,ui,a,r} \qquad \text{(INT-M17)}$$

$$QQARM_{c,a,r} = ac\_a_{c,ui,a,r} \left(delta\_a_{c,ui,a,r} * QMA_{c,ui,a,r}^{-rhoc_{c,u,r}} + \left(1 - delta\_a_{c,ui,a,r}\right) * QDNL\_A_{c,ui,a,r}^{-rhoc_{c,u,r}} \right)^{-1/rhoc_{c,u,r}} \qquad \text{(INT-M5a)}$$

$$QMA_{c,ui,a,r} = QDNL\_A_{c,ui,a,r} \left(\frac{PDA_{c,ui,a,r}}{PMA_{c,ui,a,r}} * \frac{delta\_a_{c,ui,a,r}}{\left(1 - delta\_a_{c,ui,a,r}\right)} \right)^{\frac{1}{1+rhoc_{c,ui,r}}} \qquad \text{(INT-M6a)}$$

Figure 12. Activity and commodity specific local content requirement



Source: Authors' compilation.

3.3 Price preference instrument

152. The price preference module allows the depiction of very specific policies where sales taxes are differentiated between imported and domestic commodities, such as a tax break on domestically sourced commodities. The module applies only in connection with the alternate intermediate input nesting.[43] A combination with the local content requirement (LCR) module is possible.

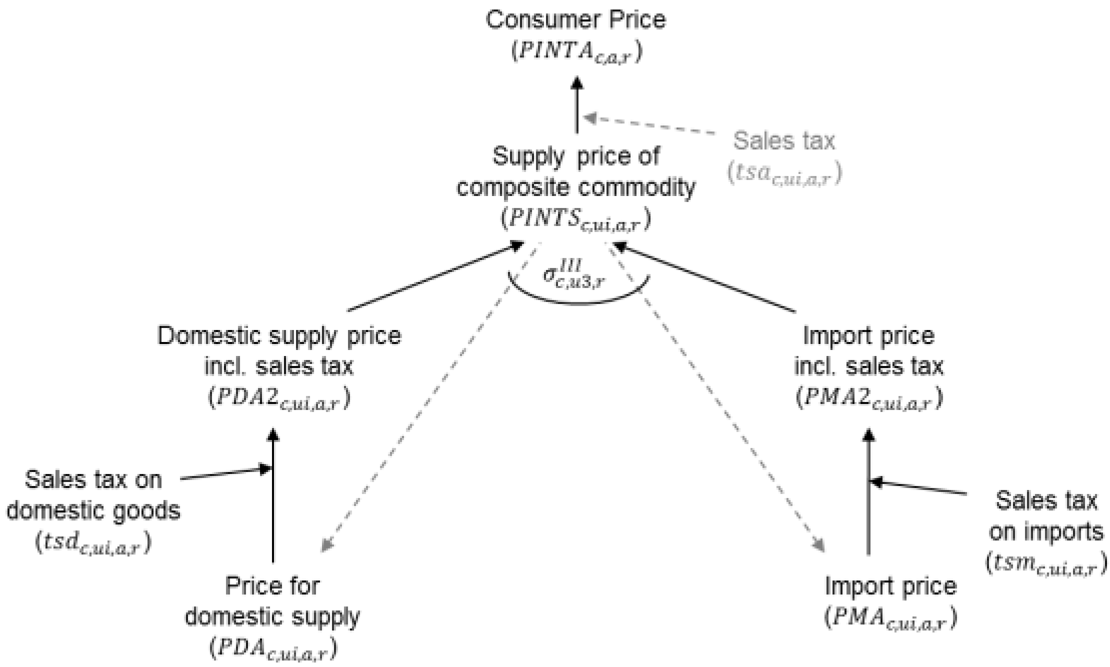
153. In the absence of the module, the sales tax is associated with the composite commodity. For the current policy instrument we shift the sales tax rate one level down and construct sales taxes on domestic commodities and sales taxes on imported commodities. This differentiation deviates from the common

43 Technically the price preference module INC file replaces the INC file of the alternate intermediate nesting. However, '$setglobal internest' must be active in the controls INC file.

practice and the concept of sales taxes. Hence, the module is not intended to act as standard specification but rather serves as instrument which can be used for the analysis of very specific policy measures.

154. Figure 13 depicts the new point where sales taxes enter in the price system. The original sales tax ($tsa_{c,ui,a,r}$) is set to zero and the new sales tax parameters, $tsm_{c,ui,a,r}$ (Sales tax for imported intermediates by activity) and $tsd_{c,ui,a,r}$ (sales tax for domestic intermediates by activity) are calibrated to reflect the original sales tax rates.

Figure 13. Structure of price preference module



Source: Authors' compilation.

155. The gap between producer prices and consumer price difference stays unchanged, but prices are reinterpreted. $PINTA_{c,a,r}$, which used to be the supply price of the composite commodity, now is a consumer price including the sales tax, with $tsa_{c,ui,a,r}$ being zero (Eq. PP-M1).

$$PINTA_{c,a,r} = PINTS_{c,ui,a,r} * \left(1 + tsa_{c,ui,a,r}\right) \quad \text{(PP-M1)}$$

156. The sales tax is shifted one level down (compare Figure 1) and the new prices $PDA2_{c,ui,a,r}$ and $PMA2_{c,ui,a,r}$ represent the domestic and import prices, each including sales taxes.

$$PDA2_{c,ui,a,r} = PDA_{c,ui,a,r} * \left(1 + tsd_{c,ui,a,r}\right) \quad \text{(PP-M2)}$$

$$PMA2_{c,ui,a,r} = PMA_{c,ui,a,r} * \left(1 + tsm_{c,ui,a,r}\right) \quad \text{(PP-M3)}$$

157. The supply price of the composite commodity is now including already sales taxes:

$$PINTS_{c,ui,a,r} * QINTA_{c,a,r} = PDA2_{c,ui,a,r} * QDA_{c,ui,a,r} + PMA2_{c,ui,a,r} * QMA_{c,ui,a,r} \quad \text{(PP-M4)}$$

158. Similarly, the Armington-CES (Eq. PP-M5) and the first order condition for profit maximisation (Eq. PP-M6) are now using the new prices and its parameters, i.e. $delta\_a_{c,ui,a,r}$ and $ac\_a_{c,ui,a,r}$, are recalibrated.

$$QINTA_{c,a,r} = ac_{a_{c,ui,a,r}} \left(delta_{a_{c,ui,a,r}} * QMA_{c,ui,a,r}^{-rhoc_{c,u,r}} + \left(1 - delta_{a_{c,ui,a,r}}\right) * QDA_{c,ui,a,r}^{-rhoc_{c,u,r}} \right)^{-1/rhoc_{c,u,r}}$$
(PP-M5)

$$QMA_{c,ui,a,r} = QDA_{c,ui,a,r} \left(\frac{PDA2_{c,ui,a,r}}{PMA2_{c,ui,a,r}} * \frac{delta\_a_{c,ui,a,r}}{(1 - delta\_a_{c,ui,a,r})} \right)^{\frac{1}{1+rhoc_{c,ui,r}}} \quad \text{(PP-M6)}$$

159. Finally, the sales taxes are income to the government and the new tax parameters are added to the tax revenue from sales taxes.

$$STAX_r = \sum_{c,u} \left(TS_{c,u,r} * PQS_{c,u,r} * QQ_{c,u,r} \right) + \sum_{c,ui,a} \left(tsa_{c,ui,a,r} * PINTS_{c,ui,a,r} * QINTA_{c,a,r} \right) + \sum_{c,ui,a} \left(tsd_{c,ui,a,r} * PDA_{c,ui,a,r} * QDA_{c,ui,a,r} \right) + \sum_{c,ui,a} \left(tsm_{c,ui,a,r} * PMA_{c,ui,a,r} * QMA_{c,ui,a,r} \right)$$
(PP-M7)

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ANNEX

Annex Table A1. Services sector concordance

	GTAP		OECD-ICIO	
Aggregate	No.	ISIC	ISIC	No.
	43	401		
43T45	44	402403	40,41	21
	45	41		
46T46	46	45	45	22
47T47	47	50,51,52,55	50,51,52	23
			55	24
	48	60,63		
48T50	49	61	60,61,62,63	25
	50	62		
51T51	51	64	64	26
52T53	52	65,67	65,66,67	27
	53	66		
			70	28
			71	29
54T54	54	K (70-74)	72	30
			73	31
			74	32
			75	33
	56	75,80,85,90,91,	80	34
55T56		99	85	35
	55,56		90,91,92,93	36
	55	92,93,95	95	37
57T57	57	n.a.		

Source: Authors' compilation.

Annex Table A2. Country mapping

	OECD-ICIO shares		GTAP		OECD-ICIO shares		GTAP		OECD-ICIO shares		GTAP
	Services	Manuf.			Services	Manuf.			Services	Manuf.	
Albania		ALB	alb	India	IND	IND	ind	Romania	ROU	ROU	rou
United Arab Emirates			are	Ireland	IRL	IRL	irl	Russia	RUS	RUS	rus
Argentina	ARG	ARG	arg	Iran			irn	Saudi Arabia	SAU	SAU	sau
Armenia			arm	Iceland	ISL	ISL		Senegal			sen
Australia	AUS	AUS	aus	Israel	ISR	ISR	isr	Singapore	SGP	SGP	sgp
Austria	AUT	AUT	aut	Italy	ITA	ITA	ita	Serbia		SRB	
Azerbaijan			aze	Japan	JPN	JPN	jpn	El Salvador			slv
Belgium	BEL	BLX	bel	Kazakhstan			kaz	Slovak Republic	SVK	SVK	svk
Bangladesh			bgd	Kenya			ken	Slovenia	SVN	SVN	svn
Bulgaria	BGR	BGR	bgr	Kyrgyzstan			kgz	Sweden	SWE	SWE	swe
Bosnia and Herzegovina		BIH		Cambodia	KHM	KHM	khm	Thailand	THA	THA	tha
Bahrain			bhr	Korea	KOR	KOR	kor	Tunisia			tun
Belarus			blr	Kuwait			kwt	Turkey	TUR	TUR	tur
Bolivia			bol	Lao People's Democratic Republic			lao	Chinese Taipei	TWN	TWN	twn
Brazil	BRA	BRA	bra	Sri Lanka			lka	Tanzania			tza
Brunei Darussalam	BRN			Lithuania	LTU	LTU	ltu	Uganda			uga
Botswana			bwa	Luxembourg	LUX	LUX	lux	Ukraine			ukr
Canada	CAN	CAN	can	Latvia	LVA	LVA	lva	Uruguay			ury
Switzerland	CHE	CHE	che	Morocco			mar	United States	USA	USA	usa
Chile	CHL	CHL	chl	Madagascar			mdg	Venezuela			ven
China (People's Republic of)	CHN	CHN	chn	Moldova		MDA		Viet Nam	VNM	VNM	vnm
Cote d'Ivoire			civ	Mexico	MEX	MEX	mex	South Africa	ZAF	ZAF	zaf
Cameroon			cmr	Former Yugoslav Republic of Macedonia		MKD		Zambia			zmb
Colombia			col	Malta	MLT	MLT	mlt	Zimbabwe			zwe
Costa Rica			cri	Montenegro		MNE		Rest of World	ROW	ROW	
Cyprus	CYP	CYP	cyp	Mongolia			mng	South Central Africa			xac
Czech Republic	CZE	CZE	cze	Mozambique			moz	Rest of Central America			xca
Germany	DEU	DEU	deu	Mauritius			mus	Caribbean			xcb
Denmark	DNK	DNK	dnk	Malawi			mwi	Central Africa			xcf
Ecuador			ecu	Malaysia	MYS	MYS	mys	Rest of East Asia			xea
Egypt			egy	Namibia			nam	Rest of Eastern Africa			xec
Spain	ESP	ESP	esp	Nigeria			nga	Rest of Eastern Europe			xee
Estonia	EST	EST	est	Nicaragua			nic	Rest of EFTA			xef
Ethiopia			eth	Netherlands	NLD	NLD	nld	Rest of Europe			xer
Finland	FIN	FIN	fin	Norway	NOR	NOR	nor	Rest of North America			xna
France	FRA	FRA	fra	Nepal			npl	Rest of North Africa			xnf
United Kingdom	GBR	GBR	gbr	New Zealand	NZL	NZL	nzl	Rest of Oceania			xoc
Georgia			geo	Oman			omn	Rest of South Asia			xsa
Ghana			gha	Pakistan			pak	Rest of South African Customs			xsc
Greece	GRC	GRC	grc	Panama			pan	Rest of Southeast Asia			xse
Guatemala			gtm	Peru			per	Rest of South America			xsm
Hong Kong, China	HKG	HKG	hkg	Philippines	PHL	PHL	phl	Rest of Former Soviet Union			xsu
Honduras			hnd	Poland	POL	POL	pol	Rest of the World			xtw
Croatia		HRV	hrv	Portugal	PRT	PRT	prt	Rest of Western Africa			xwf
Hungary	HUN	HUN	hun	Paraguay			pry	Rest of Western Asia			xws
Indonesia	IDN	IDN	idn	Qatar			qat				

a) Note by Turkey: The information in this document with reference to “Cyprus” relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the “Cyprus” issue.

b) Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Source: Authors’ compilation.