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METRO Version 3

Model Documentation

This document is an update of METRO Version 2 Model documentation, TAD/TC/WP/RD(2019)1/FINAL.

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1. Modelling Trade at the OECD: METRO v3, base model

This document provides a detailed description of the OECD Trade model METRO (ModElling TRade at the OECD), Version 3. The documentation is an update of the second version released in 2019. Three major changes have been introduced: 1) there is a new land allocation module to better represent land supply; 2) the natural resources factor is reclassified as land in the forest sector; and 3) factor market modelling was adapted to incorporate the new module. In addition to these changes to the standard model, a new model database is available. Accordingly, the database section of the documentation has also been updated

1.1. Introduction

1. METRO, the OECD Trade Model, 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). In particular, 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 version 10 see Aguiar et al., 2019), 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 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. METRO 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.

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

[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.

example, households are assumed to maximise utility using a Stone-Geary utility function, which allows for subsistence consumption expenditures. 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. The three-stage Armington approach avoids extreme specialisation and price fluctuations which are often obtained with other trade assumptions; however, it bears the shortcoming that small numbers stay small and big numbers remain big, thus limiting the possibility to model structural changes in trade (i.e. this 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 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 the specific analytical purposes. The base model is run (calibrated) to determine the initial parameter values. Experiments are then introduced separately, using data from the base model run. This documentation starts with a 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.

6. The core model is extended with modules. Some of the modules, for example local content requirement, are explained in Annex A. For additional modules and model documentation see also:

- OECD (2017), "Metro development: Modelling Non-Tariff Measures and Estimation of Trade Facilitation Impacts" [TAD/TC/WP(2016)20/FINAL]. This document discusses modelling non-tariff barriers in CGE models and details the modelling of iceberg costs, Willingness to Pay and tariff rate quotas in the METRO model.
- OECD (2018), "Metro development: The ICIO-TiVA module – A method to analyse global value chains with METRO". OECD, [TAD/TC/CA/WP/RD(2018)]. This paper documents and describes the 'ICIO-TiVA module', a module for Global Value Chain (GVC) analysis using the METRO model. The methodology follows Greenville et al. (2017) and has been adapted to use METRO output, in the form of base data and simulation results, to generate a pre- and post-simulation inter-country input-output (ICIO) table. The module output produces GVC indicators similar to the approach used in the OECD-WTO TiVA database

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

- Van Tongeren, F. and D. Flaig (2017), "Capital Accumulation in a Comparative Static Model". This technical note explains how the Capital Accumulation module, incorporates accumulation effects into METRO.
- OECD (2019), "Land allocation representation in the METRO model: Technical Documentation" [TAD/TC/CA/WP/RD(2019)4/FINAL]. This document describes the land allocation module, which allows for better representation of the constraints in production related to land by implementing a 4-tier nesting of CET functions for land supply.
- The technical note *Metro Split Programme* explains how to use the GAMS program METRO_split.gms, which is available on the model's community page. The program disaggregates user-selected sectors and commodities in the database. For example, with the program and additional input information, the user can split the iron sector from the GTAP sector iron and steel. METRO_split.gms is based on the split program in CGE-Box by Wolgang Britz. The program is adapted for METRO by accounting for the agent specific commodities in the model database.
- The technical note *Adjusting tax rates in the base data in METRO* is also available on the model's community page. It describes how to set up a simulation to adjust tax policies while limiting large adjustments in the database.

7. A graphical user interface (GUI) has been developed for the METRO model to increase accessibility and facilitate its use. The model interface makes it possible to run a simulation in METRO using only the interface and an excel spreadsheet without needing to code in GAMS. The interface is based on an existing package, "GAMS Graphical user Interface generator" by Wolfgang Britz (GGIG, Britz, 2010a/b and Britz 2014a). Accordingly, this model documentation is accompanied by the *METRO v3 Interface User Guide* [TAD/TC/WP/RD(2020)1/FINAL] .

1.2. The model structure

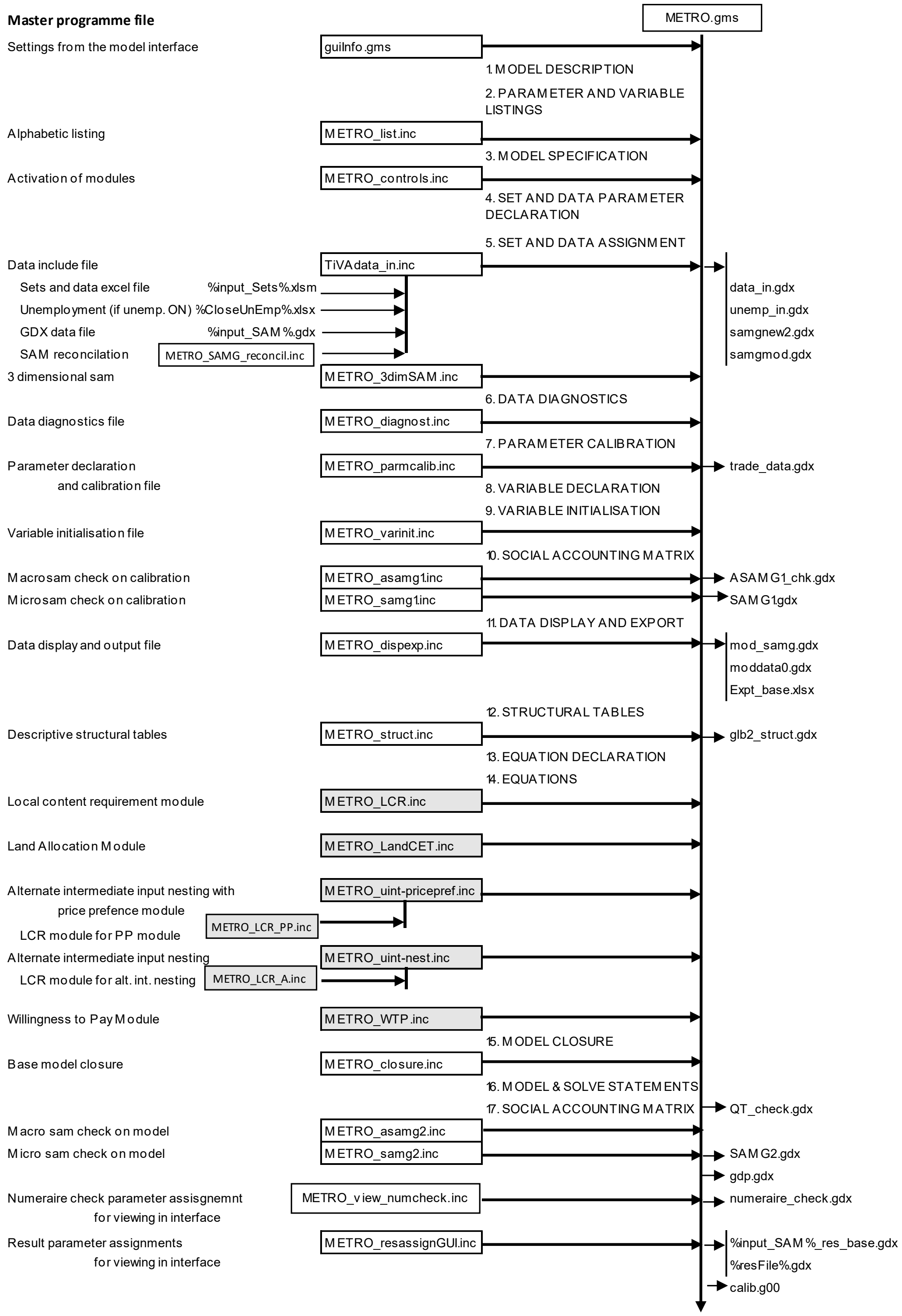
8. The model consists of one master GAMS file (GMS) and a series of include files (INC) and various other supporting files as listed in Table 1. Data is read into the model using a GAMS Data Display file (GDX) and an excel file. These files contain the basic SAM data (GDX) and definitions of set, variable 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 programmes
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.

Figure 1. Model file structure



Notes: Grey boxes represent optional modules that are activated in the model interface. "%**%" are names of various input and output files that are project specific. Users activate modules via the interface (Section 3 Modules).
Source: Authors' compilation based on McDonald et al. (2013).

9. 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 and g00 files. The majority of the INC files only need attention if the user is making changes to the core model code. However, the user needs to pay particular attention to two 'areas'. The first is the data entry file 'TiVAdata_in.inc' and the second is the module control file 'controls.inc'. These are explored in detail in the following section.

1.2.1. The model set-up

10. Before each analysis, an appropriate aggregation of the database is chosen and the model is then calibrated to this aggregation.

Database

11. 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.

12. 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 selected in the model GUI interface.

Setting up the model

13. The model allows for different setups of the base structure as well as the application of various scenario-specific modules. The model set-up is defined in the model interface (GUI) in the calibration step using the "Model Setup" tab. In addition to the choice of elasticity sources and their scaling, the user may also define: [5]

- the target for automatic scaling of the database[6]
- small import shares for bilateral trade
- small import shares on aggregate import level
- small export shares.

14. 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.

15. The different modules are also activated in the interface at the calibration step. To date these include:

[5] See the *METRO Interface User Guide* for explicit instructions

[6] The database is scaled to improve solver performance.

- alternate intermediate input nesting (activated by default in the interface)
- local content requirement module
- price preference module
- willingness to pay
- capital accumulation
- land allocation module.

16. The user sets the model's closure assumptions using the interface. The interface selections are then incorporated into model via the file 'METRO_closure.inc'. A detailed description is provided in Section 1.4.

17. Unemployment is stipulated in the excel file 'FD_unemp.xlsx". Unemployed factor and region pairs are defined in the 'uef_factors' sheet and the base unemployment rate is set in the 'unemp_rate' sheet. Users turn unemployment "on or off" in the interface at the calibration phase.

18. The definition of the nesting structure of land use in the agriculture sector is defined by the user in the excel file 'LandCET.xlsx'. The excel file is an input into the land allocation module. Sheets "sets_agriland" identifies the nodes and 'agriland_ag' defines the structure of the nesting in the agriculture sectors. The structure is the same for all regions, but elasticities may be region specific. Default elasticities for the module are either sourced from the OECD's Policy Evaluation Model (PEM), or defined by the user in the spreadsheet 'agriland_elast.'

1.2.2. Model checks[7]

19. The model comes with a set of automatic basic checks of the database and calibration. If these fail, the model run is aborted.

20. Whenever the user makes any changes to the model or to the model data, the following 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.

- *Slack variables*: All slack variables should equal zero or 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, the slacks are reported at the end of the list of variables.)
- *Check the Left hand sides*: Search for 'LHS' in the LST file; after finding the first occurrence of 'LHS', search for '***'. Any equations incorrectly specified 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.)
- *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 and check DIFFASAMG2 and CNTASAMG2, which should be zeroes or close to zero. Second, check the Micro SAM: search for and check

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

DIFFSAMG2 and CNTSAMG2, which should also be zero or close to zero. (Note: if the version of GAMS used has indexing for the list file select DISPLAY.)

- *Check the numéraire using the model interface*: Run a calibration after changing the numéraire multiplier in the "Numéraire Check" tab to 2. In the results viewer, open the result file "numeraire_check.gdx." All prices and the parameter ASAMG2_Check should equal 2. If the model passes all these checks, it will (usually) be correct.

1.3. Formal description of the model

21. 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; Section 1.3.3 provides the details on commodity market structure, including use markets; Section 1.3.4 provides details of the production structure; Section 1.3.5 sets out the 'institutions' or final demand markets; Section 1.3.6 describes the GLOBE region; and Section 1.3.7 describes the market clearing conditions.

1.3.1. Modelling conventions[8]

22. The equations for the model are set out in nine 'blocks', each of which can contain 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

[8] This section is largely reproduced from McDonald et al. (2013).

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

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

24. A series of conventions are adopted for the naming of variables and parameters. These conventions are not a requirement of the modelling language, but rather to facilitate the reading of the model.

- All VARIABLES are in upper case.
- 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

25. Rather than writing out each 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 needs to be specified only once.

26. 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 individual accounts that relate 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 organisation process.

27. Tables 2 to 6 contain in alphabetical order the full lists of sets, variables and parameters. 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 margin services
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 (ad valorem) accounts by use categories	*wwugn(wwu)*	wwu without Globe region
tmsu(sac)	Tariff (specific) accounts by use categories		
teu(sac)	Export subsidy by use category		
Subsets specified by user (in excel spreadsheet)			
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	*f3(ff)*	Factor inputs to FAG at level 2
cotp(c)	Transport commodities	*l(f)*	Labour Factors
cuti(c)	Utility commodities	*ls(l)*	Skilled Labour Factors
cser(c)	Service commodities	*lu(l)*	Unskilled Labour Factors
cagg	Aggregate commodity groups	*k(f)*	Capital Factors
Subsets of a		*lnd(f)*	Land factors
aagr(a)	Agricultural activities	*uef(f,r)*	Unemployed factors by region
anat(a)	Natural resource activities	***Subsets of w***	
afd(a)	Food activities	*wgn(w)*	Rest of world without Globe
aind(a)	Industrial activities	*wagg*	Aggregate region groups
aotp(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	*aq(a,r)*	Activities and regions with domestic production
ctn2(c)	Non trade margin commodities	*aqn(a,r)*	Activities and regions without domestic production
ce(c,u,r)	Export commodities	*aqx(a,r)*	Activities and regions with CES fn at Level 1
cen(c,u,r)	Non-export commodities	*aqxn(a,r)*	Activities and regions with Leontief fn at Level 1
cer(c,u,w,r)	Export commodities by region	*aleon(a)*	Activities with Leontief top level prodn function
cern(c,u,w,r)	Non-export commodities by region	***set of regions, r, and its subsets***	
cm(c,u,r)	Imported commodities	*r*	SAM regions
cmn(c,u,r)	Non-imported commodities	*ragg*	Aggregate region groups
cmr(w,c,u,r)	Imported commodities by region	*rgn(r)*	SAM Regions without Globe
cmrn(w,c,u,r)	Non-imported commodities by region	*ref(r)*	Reference region
cmrs(w,c,u,r)	Small shares imported commodities by region	*rleon(r)*	Regions with Leontief top level prodn function
cmrsn(w,c,u,r)	Non-small shares imported commodities by region	*ror(w,h,r)*	Remittances outflows by partner region
cms(c,u,r)	Commodities with small shares	*rorn(w,h,r)*	No remittances outflows
cmrl(w,c,u,r)	Large shares imported commodities by region	*rir(h,w,r)*	Remittances inflows by partner region
cmrln(w,c,u,r)	Non-large shares imported commodities by region	*rirn(h,w,r)*	No remittances inflows
cml(c,u,r)	Commodities with large shares	***Macro SAM that facilitates checking model calibration***	
cx(c,r)	Comm. produced domestically	*ss*	ASAM categories
cxn(c,r)	Comm. NOT produced domestically AND imported	***Various other sets declared to facilitate aspects of model operations***	
cd(c,u,r)	Comm. produced and demanded domestically	*sacn(sac)*	SAM accounts excluding TOTAL
cdn(c,u,r)	Comm. NOT produced and demanded domestically	*ssn(ss)*	ASAM categories excluding TOTALS
cintd(c,r)	Comm. with intermediate demand by region	*fcons*	Set for parameters controlling program flow
cintdn(c,r)	Comm. without intermediate demand by region	*mcons*	Set for parameters controlling model content
cqq(c,u,r)	Comm. and uses and regions with CES fn at supply nest		
cqqn(c,u,r)	Comm. and uses and regions with Leontief fn at supply nest		
cqs(c,u,r)	Comm. and uses and regions with CES fn at production nest		

Table 2. List of sets (continued)

Special sets for modules			
Activation of the alternate intermediate input nests		***Sets for land allocation module***	
ui(u)	Intermediate use	*af*	Factor CET nesting aggregate
uin(u)	Final use categories	*af1(af)*	Factor CET nesting aggregate - Level 1
ri(r)	Activation of equation for alternate int. use nesting	*af2(af)*	Factor CET nesting aggregate - Level 2
rin(r)	Activation of without alternate int. use nesting	*af3(af)*	Factor CET nesting aggregate - Level 3
		af4(af)	Factor CET nesting aggregate - Level 4

Table 3. List of mapping sets

The model also makes use of a series of mapping files to link sets		*map_tff_f(tff,f)*	Factor taxes to factors reverse
map_w_tmr(w,tmr)	*Ad valorem Tariff mapping*	*map_aagg_a(aagg,a)*	*Mapping from activities to aggregate activities*
map_tmr_w(tmr,w)	Ad valorem Tariff mapping reverse	*map_cagg_c(cagg,c)*	Mapping from commodities to aggregate commodities
map_w_tmrs(w,tmrs)	Specific Tariff mapping	*map_wagg_w(wagg,w)*	Mapping from regions to aggregate regions
map_tmrs_w(tmrs,w)	Specific Tariff mapping reverse	*map_ragg_r(ragg,r)*	Mapping from regions to aggregate regions
map_w_ter(w,ter)	Export tax mapping	*map_fag_f3(fag,f3)*	Mapping from natural factors f to aggregates
map_ter_w(ter,w)	Export tax mapping reverse	***Mappings used only for the Land Allocation Module***	
map_c_w_marg_u(c,w,owatpmarg,u)	Trade margin mapping of owatpmarg to ct2 and w	*map_fag_f3(fag,f3)*	Mapping from natural factors f to aggregates
map_marg_w(owatpmarg,w)	Trade margin mapping of w to owatpmarg	*map_af(f,af,af,af,af,a)*	CET nesting aggregate - All mapping
map_r_w(r,w)	Region to trade partner mapping	*map_af1(f,af,af)*	CET nesting aggregate - Level 1
map_w_r(w,r)	Region to trade partner mapping	*map_af2(f,af,af)*	CET nesting aggregate - Level 2
map_wwu_r(wwu,r)	Region to trade partner mapping by use	*map_af3(f,af,af)*	CET nesting aggregate - Level 3
map_f_tff(f,tff)	Factor taxes to factors	*map_af4(f,af,a)*	CET nesting aggregate - Level 4

Table 4. List of variables

ADFD(ff,a,r)	Shift parameter for factor and activity specific efficiency	*HEXP(h,r)*	Household consumption expenditure
ADFDaADJ(a)	Activity Scaling Factor for flow parameter on ADFD	*HHLDSAV(h,r)*	Household savings
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 functions for QVA	*KAPWOR(r)*	Current account balance
DADX(r)	Partial scaling factor for Shift parameter on CES functions 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 consumption
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 and aggregates
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 comm'y c from region with small shares
ER(r)	Exchange rate (domestic per world unit)	*PMR(w,c,u,r)*	Domestic price of imports of comm'y from regions and aggregates
ERPI	Exchange rate index - Global numeraire	*PMS(c,u,r)*	Dom price of imports of comm'y c from region with large shares
ETAX(r)	Export tax revenue	*PPI(r)*	Producer (domestic)
FD(ff,a,r)	Demand for factor f by activity a in r	*PQD(c,u,r)*	Consumer price of composite commodity c
FS(f,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 imports from all regions)
GDP(r)	Gross Domestic Product by Expenditure definition	*PVA(a,r)*	Value added price for activity a in r
GLOBESLACK	Slack variable for Globe	*PWE(c,u,w,r)*	World price of exports of commodity c from region r in dollars

Table 4. List of variables (continued)

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

Source: Authors' compilation.

Table 5. List of model parameters

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

Table 5. List of model parameters (*continued*)

mod_elaste(c,u,r)	Level 1 CET elasticities used in the model	*tf01(ff,a,r)*	0-1 par for flexing of factor use tax rates
mod_elastm(c,u,r)	Level 1 CES elasticities used in the model	*tf02(ff,a,r)*	tf for calibration of production functions
mod_elastre(c,u,r)	Level 2 CET elasticities used in the model	*tfb(ff,a,r)*	Factor use tax rate
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,u,r)*	0-1 par for flexing of Ad valorem Tariff rates on comm'ies
qcdconst(c,h,r)	Volume of subsistence consumption	*tmb(w,c,u,r)*	Ad valorem Tariff rates on comm'y imported from region w
qgdconst(c,r)	Government demand volume	*tmreal(w,c,u,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
qinvdconst0(c,r)	Initial Investment demand volume	*ts01(c,u,r)*	0-1 par for flexing of sales tax rates
remrYHF0(w,h,r)	Initial Remittance rate	*tsb(c,u,r)*	Base sales tax rate
remrYHFb(w,h,r)	Base Remittance rates	*tv01(c,r)*	0-1 par for flexing of value added tax rates
remrYHF01(w,h,r)	0-1 par for potential flexing of Household saving rates	*tvb(c,r)*	Base Value added tax rates
rhoc(c,u,r)	Elasticity parameter for Armington CES function	*tx01(a,r)*	0-1 par for flexing of indirect tax rates
rhoe(c,u,r)	Elast parameter for CET over exports by aggregate region	*txb(a,r)*	Base indirect tax rate on activity a
rhofd(ff,a,r)	Elasticity parameter for CES prodn fns for Aggregated FD	*tyf01(f,r)*	0-1 par for flexing of direct tax rates on factors
rhom(c,u,r)	Elast parameter for Armington CES over imports by aggregate region	*tyfb(f,r)*	Factor income tax rate
rhot(c,u,r)	Elasticity parameter for Output CET function	*tyh01(h,r)*	0-1 par for flexing of direct tax rates on h'holds
rhova(a,r)	Elasticity parameter for CES production function for QVA	*tyhb(h,r)*	Direct tax rate on household h
rhox(a,r)	Elasticity parameter for CES production function for QX in r	*unemp_rate(f,r)*	Unemployment rates
shh0(h,r)	Initial Household saving rates	*use(c,a,r)*	use matrix transactions
shh01(h,r)	0-1 par for potential flexing of Household saving rates	*vqcdsh(c,r)*	Share of commodity c in total household commodity demand
shhb(h,r)	Base Household saving rates	*vqdsh(c,u,r)*	Share of value of domestic output for the domestic market
sumelast(h,r)	Weighted sum of income elasticities	*vqesh(ref)*	Share of total Exports by reference regions
te01(c,u,w,r)	0-1 par for flexing of export taxes on comm'ies	*yhelast(c,h,r)*	(Normalised) household income elasticities
teb(c,u,w,r)	Export tax rates on exports of comm'y c to region w		

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	*impmarg(w,c,cp,u,r)*	Margins of type c paid by comm'y cp on r's imports from region w
ELASTF(r,h)	Frisch parameters for LES demand system	*impmargotp(w,owatpmarg,cp,u,r)*	Margins of type c paid by comm'y cp on r's imports from region w
ELASTFD(ff,a,r)	Elasticities for CES Production function level 3	*imprtsh(w,c,u,r)*	import trade shares
ELASTM(c,r)	Elasticities for Armington CES functions	*LABUSE(ff,a,r)*	Labour use by activity
ELASTMG(c,r)	Elasticities for Armington CES functions	*mod_cont(mcons)*	values for parameters controlling model content
ELASTRE(c,r)	Elasticities for CET over regions Level 3	*pop(h,r)*	population data by household
ELASTRM(c,r)	Elasticities for Armington CES over regions Level 3	*popn(r)*	GTAP population data
ELASTRMG(c,r)	Elasticities for Armington CES over regions	*SAMDOM(sac,sacp,u,r)*	Domestic Matrix by use
ELASTVA(a,r)	Elasticities for CES Production function level 2	*SAMG(sac,sacp,r)*	the GTAP SAM database
ELASTVAG(a,r)	Elasticities for CES Production function level 2	*SAMGFACT(sac,sacp,r)*	Factor use by activity
ELASTX(a,r)	Elasticities for CES Production function level 1	*SAMIMP(sac,sacp,u,r)*	Import Matrix by use
ELASTY(c,h,r)	Income elasticities of demand for LES demand system	*samscal*	SAM scaling factor
FACTUSE(ff,a,r)	Factor use by activity	*un_rate(r,f)*	Unemployment rates
flow_cont(fcons)	values for parameters controlling program flow		
Parameters for calibration checks			
ASAMG1(sac,sacp,r)	Aggregate SAM for calibration check	*cqsh(c,u,r)*	share of imports in supply for cqq
ASAMG2(sac,sacp,r)	Aggregate SAM for base run check	*cqssh(c,u,r)*	share of exports in domestic production for cqs
CHKSAMG1(sac,r)	Check on row and column totals	*deltafdchk(ff,a,r)*	Check on share parameters for Aggregated FD
cmrCNT	Count of activity import transactions	*deltarCHK(c,u,r)*	Check on deltar
cmrlCNT	Count of large shares imported commodities by region	*deltavacheck(a,r)*	Check on deltava
cmrsCNT	Count of small shares imported commodities by region	*deltaxCHK(r)*	Check on share parameter for CES production functions for QX
CNTSAMG1(r)	Count of non-zero entries in DIFFSAMG1	*DIFFSAMG1(sac,sacp,r)*	Differences between SAMG and SAMG1
CNTSAMG2(r)	Count of non-zero entries in DIFFSAMG1	*DIFFSAMG2(sac,sacp,r)*	Differences between SAMG and SAMG1
COMTAXE0(r)	Check on export taxes	*gammarchk(c,u,r)*	Check on gammar
COMTAXM0(r)	Check on import tariffs	*HCON(c,r)*	Household consumption
COMTAXS0(r)	Check on sales taxes	*ioqmCHK(c,u,r)*	Check on ioqm
COMTAXT0(r)	Check on total commodity taxes	*ioqmrqmsCHK(c,u,r)*	Check on ioqmrqms

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

ioqqCHK(c,u,r)	Check on ioqq	*qqdif(c,u,r)*	Check on QQ0
numerchk	numeraire check value	*QT_chk(w,c,u,r)*	Check on QTL v QT0
perDIFFSAMG1(sac,sacp,r)	Percentage differences between SAMG and SAMG1	*QT0sum(c,u,r)*	Sum by w of QT0
perDIFFSAMG2(sac,sacp,r)	Percentage differences between SAMG and SAMG1	*QTsum(c,u,r)*	Sum by w of QT
QECALIB(c,u,r)	CALIBRATED VALUE OF QE0	*SAMG1(sac,sacp,r)*	Post calibration Global SAM
QEDIFF(c,u,r)	DIFFERENCE BETWEEN CALIBRATED AND ACTUAL QE0	*SAMG12CHK(sac,sacp,r)*	Check on comparison of SAMG1 with SAMG2
QER_chk(c,u,w,r)	Check on QER	*SAMG12CHK_alt(sac,sacp,r)*	Check on comparison of SAMG1 with SAMG2
QM02(c,u,r)	alternate calculation	*SAMG2(sac,sacp,r)*	Post Solve Global SAM
qm02chk(c,u,r)	Check on QM0	*SAMG2CHK(sac,r)*	Check on row and column totals
QM03(c,u,r) a	alternate calculation	*TOTCON(r)*	Check on total consumption
qm03chk(c,u,r)	Checkon QM0	*TOTPROD(r)*	Check on total production
QMCALIB(c,u,r)	CALIBRATED VALUE OF QM0	*vqcdshCHK(r)*	Check on CPI weights
QMDIFF(c,u,r)	DIFFERENCE BETWEEN CALIBRATED AND ACTUAL QM0		

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 for 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 for of composite commodity c
ioqmaqq(c,u,a,r)	Share of imports in composite intermediate supply by activity	*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)*	Aggregate quantity of intermediates used by activity a in r
		QINTA(c,a,r)	Activity specific price for aggregate intermediate input
		QMA(c,u,a,r)	Activity specific imports of commodity c
		LCR – Alternate intermediate input nesting	
lcrsh_A(c,a,r)	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
		Land Allocation Module	
WF0_CET1(f,af,r)	Factor price aggregate CET nesting - Level 1	*WF_CET1(f,af,r)*	Factor price aggregate CET nesting - Level 1
WF0_CET2(f,af,r)	Factor price aggregate CET nesting - Level 2	*WF_CET2(f,af,r)*	Factor price aggregate CET nesting - Level 2
WF0_CET3(f,af,r)	Factor price aggregate CET nesting - Level 3	*WF_CET3(f,af,r)*	Factor price aggregate CET nesting - Level 3
WF0_CET4(f,af,r)	Factor price aggregate CET nesting - Level 4	*WF_CET4(f,af,r)*	Factor price aggregate CET nesting - Level 4
FS0_CET1(f,af,r)	Factor aggregate CET nesting - Level 1	*FS_CET1(f,af,r)*	Factor aggregate CET nesting - Level 1
FS0_CET2(f,af,r)	Factor aggregate CET nesting - Level 2	*FS_CET2(f,af,r)*	Factor aggregate CET nesting - Level 2
FS0_CET3(f,af,r)	Factor aggregate CET nesting - Level 3	*FS_CET3(f,af,r)*	Factor aggregate CET nesting - Level 3
FS0_CET4(f,af,r)	Factor aggregate CET nesting - Level 4	*FS_CET4(f,af,r)*	Factor aggregate CET nesting - Level 4
af_sigma(f,af,r)	Elasticity of transformation for node in the factor CET nesting structure		
ECET_PEM(r,)*	PEM elasticities for CET nesting structure		

Table 7. Module parameters and variables (*continued*)

Parameter		Variable	
		Willingness to pay module	
bmr01(w,c,u,r)	0-1 par for flexing of WTP on commodities	*BD(c,u,r)*	Distribution parameter on domestic goods QD
dabbmr(w,c,u,r)	Change in base WTP on comm'y imptd by regn	*BDRATQ(c,u,r)*	Ratio of distribution parameter on domestic goods
ioqxqxc(a,c,r)	IO coefficient for commodities produced by each activity	*BHC(h,r)*	Distribution parameter on household consumption
		BHHD(h,r)	Distribution parameter on household consumption and savings
		BM(c,u,r)	Distribution parameter on composite imports QM
		BMR(w,c,u,r)	Distribution parameter on imports by region QMR
		BMRADJ(r)	WTP scaling factor for implementing shocks
		BMRATQ(c,u,r)	Ratio of distribution parameters on composite imports
		BMRRATM(w,c,u,r)	Ratio of distribution parameter on goods in agent consumption
		BQ(c,u,r)	Distribution parameter on composite goods QQ
		BQRATH(c,h,r)	Ratio of distribution parameter on domestic in composite goods
		BSAV(r)	Distribution parameter on savings
		BU(u,r)	Distribution parameter on agent
		BX(a,r)	Distribution parameter on activity QX
		DBMR(r)	Uniform WTP scaling factor for implementing shocks
		DOMSAV(r)	Domestic savings
		NETINV(r)	Net investment
		QMACT(r)	Actual imports received by region r from all regions
		QMICE(r)	Imports consumed by agents (differs from QMACT by iceberg affect
		SADJH(h,r)	Savings rate scaling factor by households

Source: Authors' compilation.

1.3.3. Commodity market structure by use category[9]

Use categories

28. 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 four 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 ($PS_{c,u,r}$, Equation C2 below).

29. 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

30. Export commodities are generally treated as imperfect substitutes, with the exception of exports from the Globe region (for trade and transport services) that are homogeneous. This complicates the treatment of exports. The presumption of imperfect substitution is the default presumption in this model. The 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 argument to treat exports as perfect substitutes and there are cases where such an assumption may be appropriate, e.g. supplies of unprocessed mineral products.[10]

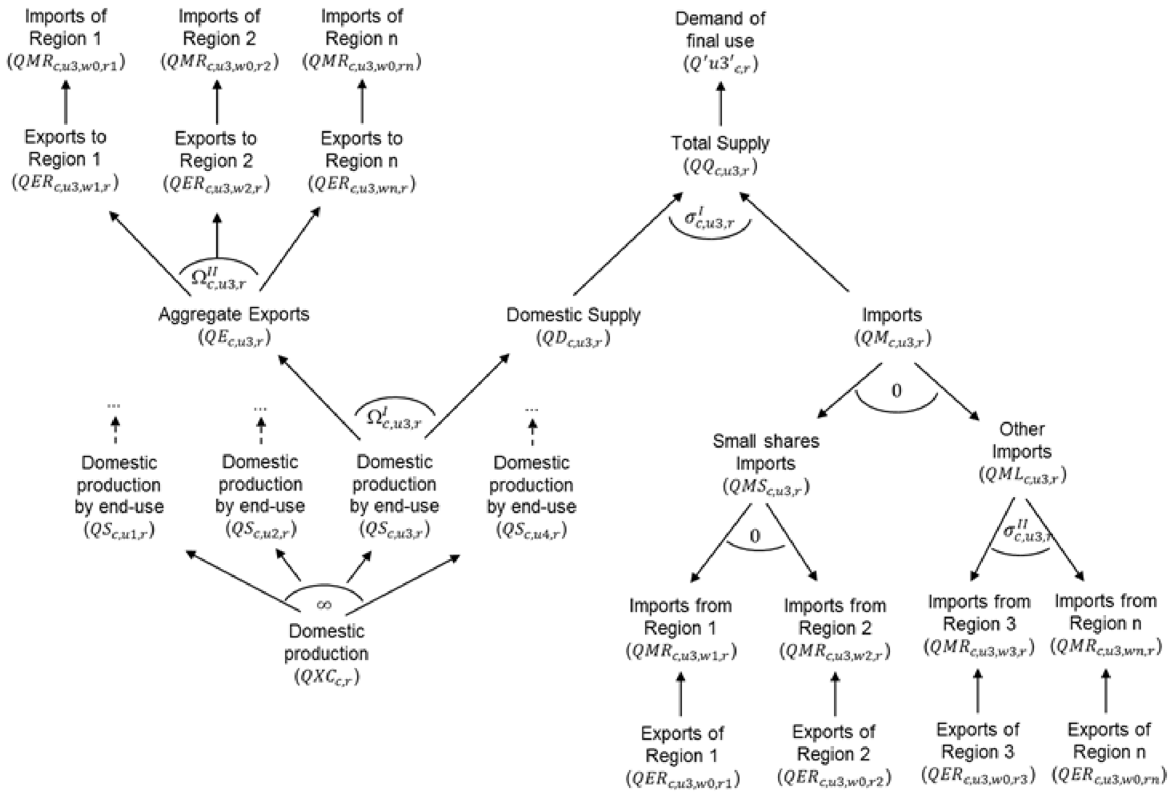
31. Imperfect substitution is introduced with a two-level Constant Elasticity of Transformation (CET) formulation which allows firms to differentiate prices on the domestic and export markets, depending on market shares and price elasticities ($\Omega^{I}_{c,u,r}$). At the first stage of the CET nest, commodity supply is distributed between the domestic market and the aggregated export market (Figure 2), while at the second stage the aggregate export supply is distributed among the different export destination regions. The responsiveness to relative price changes at 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

[9] This section is mainly based and in part reproduced from McDonald et al. (2013).

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

the import elasticities. This structure offers the possibility to depict global value chain characteristics. The distribution decision at both levels is based on relative prices: aggregate export supply is, at 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 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.

32. 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 (ERr) and one minus the export tax rate ($TE_{c,u,w,r}$) (Equation X2). 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 price 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.

33. The prices of the composite export commodities can then be expressed as simple volume weighted averages of the export prices by region, where 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 is due to the fact that a CET function is linear and homogenous, and hence Euler's theorem can be applied. Notice, however, that Equation X1 is only implemented on the set *rgn*, i.e. the Globe region 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)	$PEDEF_{c,u,r}$	$PE_{c,u,r} = \frac{\sum_w (PER_{c,u,w,r} * QER_{c,u,w,r})}{QE_{c,u,r}}$	(ce*u*rgn)	$PE_{c,u,r}$	No
(X2)	$PERDEF_{c,u,w,r}$	$PER_{c,u,w,r} = PWE_{c,u,w,r} * (1 - TE_{c,u,w,r}) * ER_r$	(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)	$CET_{c,u,r}$	$QS_{c,u,r} = at_{c,u,r} \left(gamma_{c,u,r} * QE_{c,u,r}^{rhot_{c,u,r}} + (1 - gamma_{c,u,r}) QD_{c,u,r}^{rhot_{c,u,r}} \right)^{\left(\frac{1}{rhot_{c,u,r}}\right)}$	(c*u*rgn)	$QD_{c,u,r}$	No
(X5)	$ESUPPLY_{c,u,r}$	$QE_{c,u,r} = QD_{c,u,r} * \left(\frac{PE_{c,u,r}}{PD_{c,u,r}} * \frac{(1 - gamma_{c,u,r})}{gamma_{c,u,r}} \right)^{\left(\frac{1}{rhot_{c,u,r} - 1}\right)}$	(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

34. 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, (Equation X4) with the optimum combinations of $QE_{c,u,r}$ and $QD_{c,u,r}$ determined by first-order conditions (Equation 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 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.[11] There is the possibility to assume supplies in small fixed shares to avoid eventual large terms of trade effects.

35. These quantity equations deal, however, only with composite export commodities, i.e. hypothetical commodities whose role in the model is 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 (Equation X5). In the model, the composite export commodities are CET aggregates of commodity exports to different regions ($QER_{c,u,w,r}$), and the appropriate first order condition is given by Equation X9[12]. Note, however, that Equation X9 does not define the export 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.

36. Finally, there is a need for an equilibrium condition for trade by Globe. Since Globe is an artificial construct whose sole role 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 (Equation X10).

Imports

37. Domestic demand is served from domestic supply and import supply ($QM_{c,u,r}$). Import supply is modelled as a three-stage CES function assuming imperfect substitutability between domestically produced commodities and imported commodities, displayed on the bottom right of Figure 2. The composition of domestic and imported commodities is determined at 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 which are as a consequence exposed to large relative price effects. The definition of a small import share can be freely chosen, although by default import shares of less than 0.1% are considered small. At 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%. The aggregate of 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 to each use-market.

38. 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

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

[12] Initially the formulation of X9 is not intuitive, but, as demonstrated by McDonald et al. (2013a, Appendix A1), the formulation is a straightforward manipulation of a more conventional representation. It is used because it improves model performance.

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 (Equation 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.

39. The domestic prices of imports from a region ($PMR_{w,c,u,r}$) (Equation 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 implemented only for those commodities 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

40. The model treats imports that account for 'small' shares of imports of a commodity by a region differently from 'large' shares of imports of a commodity by a region 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 these account for fixed proportions ($ioqmrqms_{w,c,u,r}$) of the total volume of imports of a commodity. The justification for this

assumption rests on 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 (Equation 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 linear and homogenous, and hence the Eulers theorem can be applied (Equation M1).

41. The prices of the composite import commodities can also be expressed as simple volume weighted averages of the import prices by region (Equation 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 that Equation M5 is only controlled by the set *cm*, in contrast to Equation X1 – the composite export price – which is also controlled by the set *rgn*, i.e. the region Globe is excluded. This reflects the fact that the region Globe imports commodities using the same trading assumption as other regions, but only exports homogenous trade and transport services, which explains the need for 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 ∩ cmn) or (cxn ∩ 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)	$ARMLEV2_{w,c,u,r}$	$QMR_{w,c,u,r} * ams_{w,c,u,r} = QML_{c,u,r}\left(\frac{PMR_{w,c,u,r}/ams_{w,c,u,r} * acr_{c,u,r}^{rhom_{c,u,r}}}{PML_{c,u,r} * deltar_{w,c,u,r}}\right)^{\left(\frac{-1}{rhom_{c,u,r}+1}\right)}$	(w*cmrl*u*r)	$QMR_{w,c,u,r}$	Yes
(M14)	$QTEQ_{w,c,u,r}$	$QT_{w,c,u,r} = \sum_{cp}\left(QMR_{w,cp,u,r} * margcor_{w,c,cp,u,r}\right)$	(w*ct2*u*rgn)	$QT_{w,c,u,r}$	No

42. 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 (Equations M10 and M11). Similarly, the quantities imported of the 'small' share commodities by source region are defined by fixed (input-output) coefficients (Equation 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.

43. The composite imports of commodities with 'large' shares are defined as CES aggregates of the imports from different regions ($QMR_{w,c,u,r}$) (Equation M13). The first order conditions come from the price definition terms for composite imports ($PML_{c,u,r}$) (Equation 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 rather 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. M13 also contains the "iceberg cost" parameter ($ams_{w,c,u,r}$), which simulates non-tariff measures on imports.

44. The composite (consumption) commodities are 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 (Equation M7), with the optimal combinations of $QM_{c,u,r}$ and $QD_{c,u,r}$ being determined by first-order conditions (Equation 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 covered by Equation M9.

45. 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 (Equation 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

46. Figure 3 gives an overview of the relations between prices. 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 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.

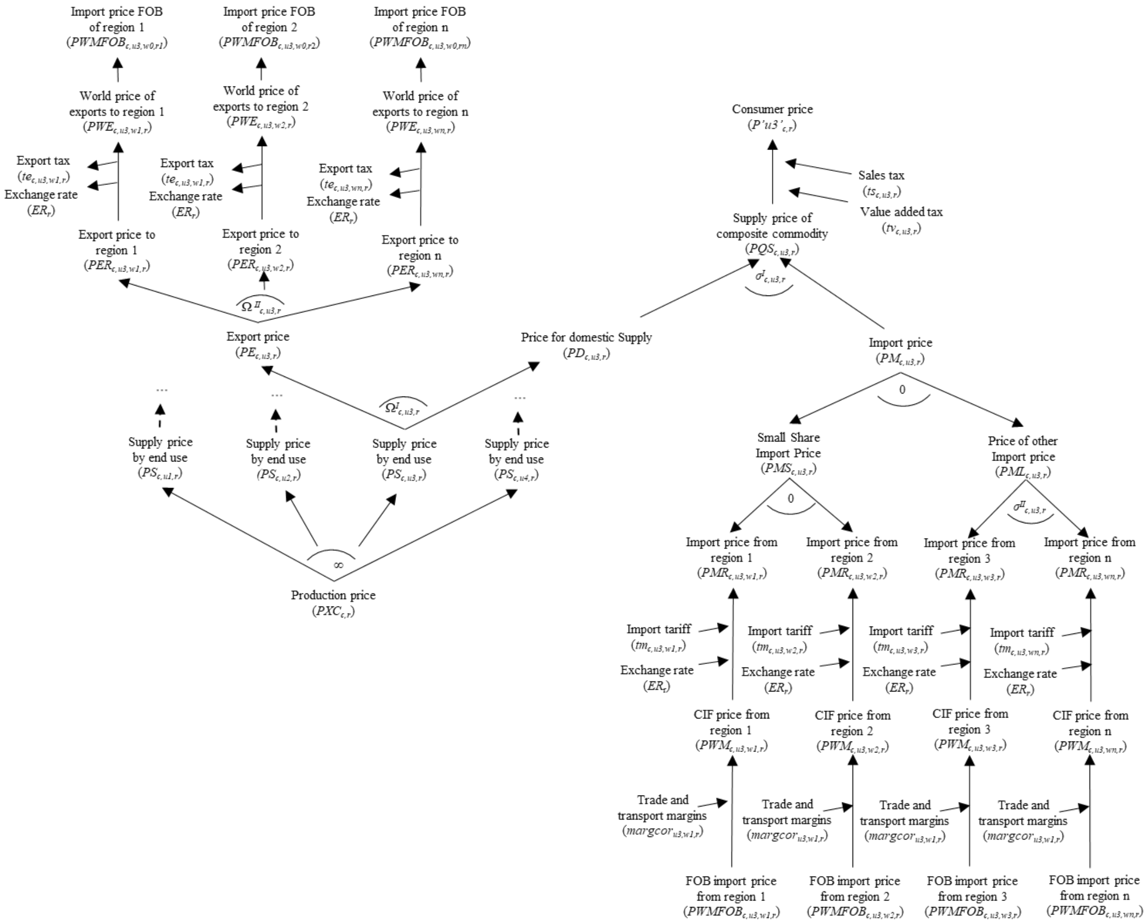
47. The composite price equations (Equations CP1 to CP6) are derived from the first order conditions for tangencies to consumption and production possibility frontiers. By exploiting Euler's theorem for linearly homogeneous functions, the composite prices can be expressed as expenditure identities rather 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 (Equation 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 (Equation 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 producer prices ($PQS_{c,u,r}$). Hence, the purchaser price is defined as the producer price plus the sales taxes (Equations CP2-CP5). This formulation means that sales taxes are levied on all sales on the domestic market, irrespective of the origin of the commodity concerned.

48. 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.

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

Figure 3. Price structure of commodity market by use category



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

49. It is also necessary to define a price numéraire for each region. For this model two alternative numéraire are defined to allow the modeller some discretion as to the choice of numéraire.[13] The consumer price indices (CPI_r) are defined as the 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 ($vqcdsh_{c,r}$) (Equation N1).

50. 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 ($vddtotsh_{c,u,r}$) (Equation N2). This provides a convenient alternative price normalization term; if the exchange rate is also fixed it serves to fix the real exchange rate.

51. Notice how both price indices to be implemented are controlled 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 are those of the reference region(s) in the model.

52. The exchange rate numéraire (Equation 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 countries 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 the global numéraire, trade balances can be seen as a 'claim' against a weighted average of exports by the group of regions.

1.3.4. Production[14]

53. 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.[15] 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 CES function over capital, land, natural resources, a skilled labour aggregate, and an aggregate of unskilled labour.

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

[14] As the production structure of METRO and its parent GLOBE model is identical, this section is largely reproduces the material in McDonald et al. (2013).

[15] 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.

54. The setup of the nesting is flexible. The set of primary inputs (*ff*) includes all the natural primary inputs in GTAP (capital, land, natural resources, and five 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.

55. 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 commodity prices (composite in use dimension) received by activities ($PXC_{c,r}$). This is a consequence of the supply matrix being a square diagonal matrix.

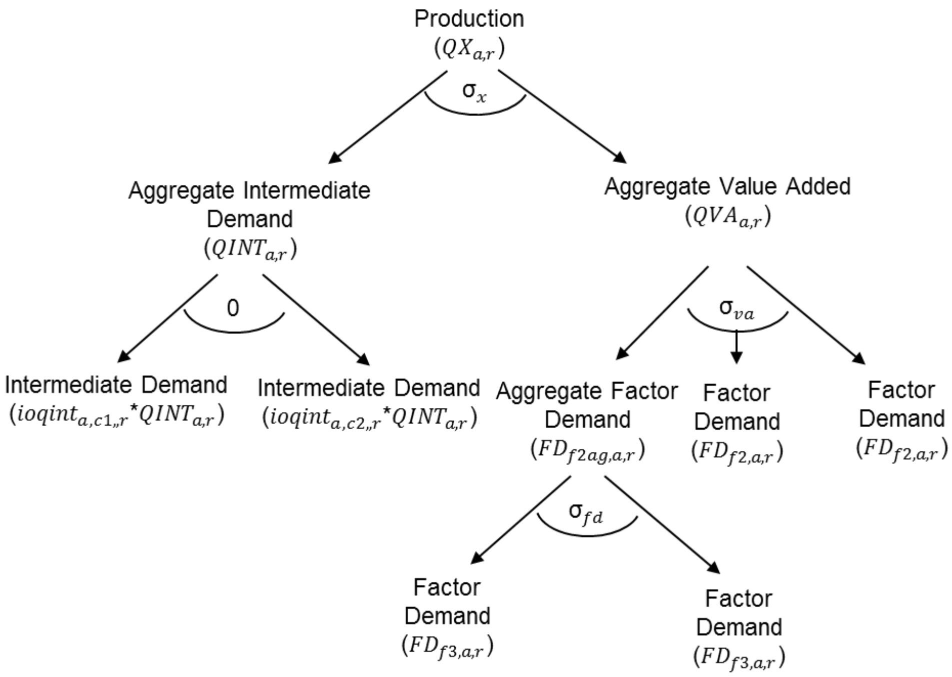
Top level

56. The output price by activity ($PX_{a,r}$) is defined by the shares of commodity outputs produced by each activity (Equation 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.[16]

57. 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 ($QINT_{a,r}$) (Equation 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 (Equation P1.3).

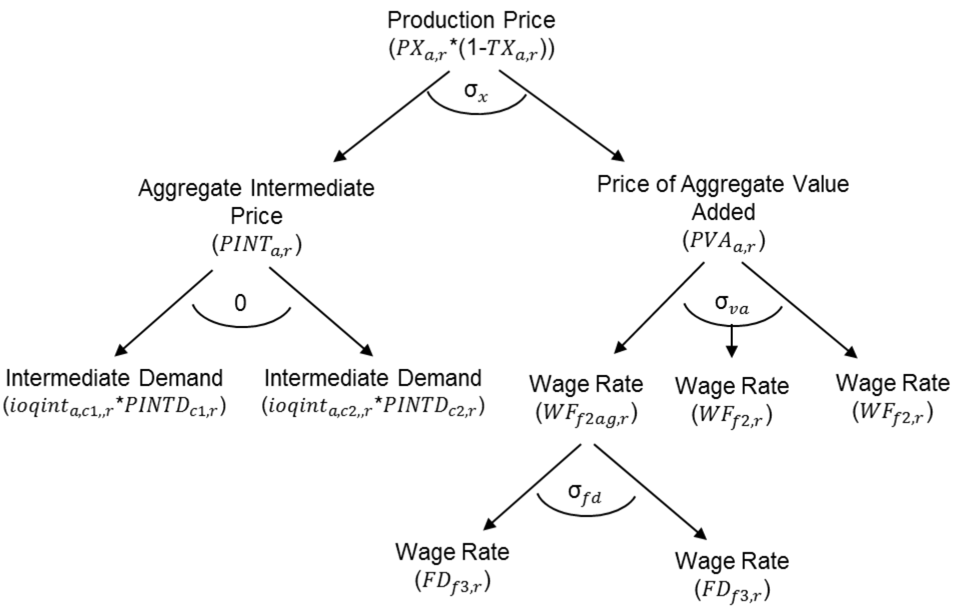
[16] When using GTAP data, $ioqxcqx_{a,c,r}$ is always a diagonal matrix.

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)	$PXDEF_{a,r}$	$PX_{a,r} = \sum_c (ioqxcqx_{a,c,r} * PXC_{c,r})$	(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)	$PINTDEF_{a,r}$	$PINT_{a,r} = \sum_c (ioqint_{a,c,r} * PINTD_{c,r})$	(a*rgn)	$PINT_{a,r}$	No
(P1.4)	$ADXEQ_{a,r}$	$ADX_{a,r} = (adxb_{a,r} + dabadx_{a,r}) * ADXADJ_r * adxadj01_{a,r} + DADX_r * adx01_{a,r}$	(a*rgn)	$ADX_{a,r}$	No
(P1.5)	$QXPRODFN_{a,r}$	$QX_{a,r} = ADX_{a,r} * \left(deltax_{a,r} * QVA_{a,r}^{-rhox_{a,r}} + (1 - deltax_{a,r}) * (aqint_{a,r} * QINT_{a,r})^{-rhox_{a,r}}\right)^{\left(\frac{-1}{rhox_{a,r}}\right)}$	(aqx*rgn)	$QX_{a,r}$	No
(P1.6)	$QXFOC_{a,r}$	$QVA_{a,r} = (aqint_{a,r} * QINT_{a,r}) * \left(\frac{PINT_{a,r}}{PVA_{a,r}} * \frac{deltax_{a,r}}{1 - deltax_{a,r}}\right)^{\left(\frac{1}{1+rhox_{a,r}}\right)}$	(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)	$COMOUT_{c,r}$	$QXC_{c,r} = \sum_a (ioqxcqx_{a,c,r} * QX_{a,r})$	(c*rgn)	$QXC_{c,r}$	No

58. The default top level production function (Equation P1.5) is a CES aggregation of aggregate primary and intermediate inputs, where the first order conditions for profit maximisation (Equation 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 ($rhox_{a,r}$), and are exogenously imposed. Note in this case the efficiency factor is declared as variable and is determined by Equation 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.[17] 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) as a result the applied efficiency factors are those from the base solution. This 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.

59. The model contains the possibility to increase demand of a specific intermediate input with the intermediate technology shifter ($aqint_{a,r}$). The shifter is generally equal to 1

[17] 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 allow for a more complex set of adjustments, although it is important to be careful about the rationale for such a set of adjustments.

in the calibration run, the activation manipulates the IO-coefficients on the second level of the production function (Equation P2.5) and the technology shifter on the first level ($aqint_{a,r}$) in a co-ordinated manner. This process is described in Section 3.4.

60. The production function (Equation 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 (Equation P1.7) and aggregate values added (Equation P1.8) are fixed proportions of the volumes 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%.[18]

61. 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 (Equation 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 (Equation 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

62. 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 the set *ff* are aggregate factors.[19] 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,[20] which are defined at the third level. 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 (Equation P2.3).

63. 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 (Equation P2.4), while

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

[19] 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, only natural factors should be subjected to factor use taxes (*TF*).

[20] 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. It is recommended for METRO that natural factors are not aggregated and in particular that land and natural resources are never aggregated, and that sector aggregates are not formed across activities that use land and natural resources in the disaggregated data.

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 ($WFDIST_{ff,a,r}$), where the parameter $WFDIST_{ff,a,r}$ captures the real wage differences across sectors and is fixed. 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 ($TF_{ff,a,r}$).

Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
	Production Block – Second Level			
(P2.1) $ADVAEQ_{a,r}$	$ADVA_{a,r} = (advab_{a,r} + dabadva_{a,r}) * ADVAADJ_r * advaadj01_{a,r} + DADVA_r * adva01_{a,r}$	(a*rgn)	$ADVA_{a,r}$	No
(P2.2) $ADFDEQ_{f,a,r}$	$ADFD_{f,a,r} = (adfdb_{f,a,r} + dadfd_{f,a,r}) * ADFDfADJ_f * ADFDaADJ_a * ADFDrADJ_r$	(f*a*rgn)	$ADFD_{f,a,r}$	No
(P2.3) $QVAPRODFN_{a,r}$	$QVA_{a,r} = ADVA_{a,r}{}^* \left[\sum_{f2}\left(deltava_{f2,a,r}(FD_{f2,a,r})^{-rhova_{a,r}}\right)\right]^{\left(\frac{-1}{rhova_{a,r}}\right)}$	(a*rgn)	$QVA_{a,r}$	No
(P2.4) $QVAFOC_{ff,a,r}$	$WFD_{f2,a,r} * WFDIST_{f2,a,r} * (1 + TF_{f2,a,r}) = PVA_{a,r} * QVA_{a,r} * \left[\sum_{f2}\left(deltava_{f2,a,r}(FD_{f2,a,r})^{-rhova_{a,r}}\right)\right]^{-1} * deltava_{f2,a,r} * FD_{f2,a,r}^{(-rhova_{a,r}-1)}$	(f2,a,rgn)	$FD_{f2,a,r}$	No
(P2.5) $QINTDEQ_{c,r}$	$QINTD_{c,r} = \sum_a (ioqint_{c,a,r} * QINT_{a,r})$	(c*rgn)	$QINTD_{c,r}$	No
	Production Block – Third Level			
(P3.1) $FDPRODFN_{ff,a,r}$	$FD_{fag,a,r} = adfag_{fag,a,r} * \left[\sum_{f3}\left(deltafd_{fag,f3,a,r} * (ADFD_{f3,a,r} * FD_{f3,a,r})^{-rhofd_{ff,a,r}}\right)\right]^{\left(\frac{-1}{rhofd_{ff,a,r}}\right)}$	(fag*a*r)	$FD_{fag,a,r}$	No
(P3.2) $FDFOC_{ff,f3,a,r}$	$WFD_{f3l,a,r} * WFDIST_{f3l,a,r} * (1 + TF_{f3l,a,r}) = WFD_{fagf,a,r} * WFDIST_{fagf,a,r} * (1 + TF_{fagf,a,r}) * FD_{fagf,a,r} * \left[\sum_{f3l} WFD_{f3,a,r} * WFDIST_{f3,a,r} * (1 + TF_{f3,a,r})\left(deltafd_{ff,l,a,r} * ADFDF_{f3,a,r} * FD_{l,a,r}^{-rhofd_{ff,a,r}}\right)\right]^{-1} * deltafd_{fagf,f3l,a,r} * ADFD_{f3,a,r}^{(-rhofd_{fag,a,r})} * FD_{f3,a,r}^{(-rhofd_{fagf,a,r}-1)}$	(l*a*r)	$FD_{l,a,r}$	No

64. Since production uses intermediate inputs, it is necessary to specify the demand for these 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 (Equation P2.5).

65. The efficiency factors are declared as variables (Equation 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 $adva01_{a,r}$ is a vector of zeroes and non-zeroes.[21] 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 – this is a closure rule decision. The applied efficiency factors are those from the base solution.

66. A similar specification is adopted for factor specific efficiency factors on the third level of the production function, i.e. a factor that can alter/adjust the stock-flow relationship between factor quantities and factor services, although it differs in the adjustment mechanism (Equation 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 region specific ($ADFDrADJ_r$) adjustments.

67. The third level of production functions (Equation P3.1) define the quantities of aggregate factors fag as CES aggregates of the labour factors *l*. As elsewhere, the efficiency factors ($adfag_{fag,a,r}$)[22] 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 (Equation 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

68. 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 (Equation F1). However, only a proportion of total factor income is available for distribution to the domestic institutional accounts ($YFDIST_{f,r}$). Allowance must be made for depreciation, which is assumed takes place at fixed rates ($deprec_{f,r}$) relative to factor incomes and the payment of factor income taxes ($TYF_{f,r}$) (Equation F2).

[21] 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 for a more complex set of adjustments. It is, nevertheless, important to be careful about the rationale for such adjustments.

[22] Parameter *adfag* is the efficiency factor for aggregate factors on the second level of the production function. Note that the current specification allows only to shock the efficiency of the first and third levels of the production functions, as well as aggregate factors formed by the third level. This is not possible for natural factors of the second level. Unlike the other efficiency factors, $adfagfa_{g,a,r}$ is not specified as a variable but as a parameter.

69. Unemployment is introduced as a mixed complementarity problem (MCP) (Equation F3). The total supply of a natural factor consists of current total demand and a stock of the factor that is currently unemployed ($UNEMP_{f,r}$) (Equation 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 by setting a lower level to the wage rate.

	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Factor Market Block			
(F1)	$YFEQ_{f,r}$	$YF_{f,r} = \sum_{a}(WFD_{f,a,r} * WFDIST_{f,a,r} * FD_{f,a,r})$	(f*rgn)	$YF_{f,r}$	No
(F2)	$YFDISTEQ_{f,r}$	$YFDIST_{f,r} = (YF_{f,r} - deprec_{f,r} * YF_{f,r}) * (1 - TYF_{f,r})$	(f*rgn)	$YFDIST_{f,r}$	No
(F3)	$UNEMPEQUIL_{f,r}$	$UNEMP_{f,r} \geq 0$	(f*rgn)	$UNEMP_{f,r}$	No
		Where *f* is a perfectly mobile factor ($f\_closure_{f,,r}$ = 1)			
(F4)	$WFDEQ_{f,a,r}$	$WFD_{f,a,r} = WF_{f,r}$	(f*a*rgn)	$WFD_{f,a,r}$	No
		Where *f* is a perfectly mobile factor ($f\_closure_{f,,r}$ = 1)			
		$WF0_{f,r} \leq WF_{f,r} \leq +\infty \ \forall uef$			

1.3.5. Institutions[23]

Households

70. Households *h* acquire income from two sources in this model: the sale of factor services and remittances (Equation H1). Household factor income ($YHF_{h,r}$) is defined as the sum of factor incomes available for distribution (Equation H2). In this variant, allowance is made for the possibility of multiple households by including a set of distribution parameters ($hvash_{h,f,r}$) that are defined as the shares of each factor demanded in the economy supplied by each household. In the case of one household, all the shares equal one.

71. After paying income taxes, households send a fixed share ($REMRYHF_{w,h,r}$) of their factor income as remittances abroad, from *r* to *w* ($REMOUT_{w,h,r}$) (Equation H3). The households *h* in destination region *r* receive remittances inflows from source country *w* in domestic currency units ($REMIN_{h,w,r}$) (Equation H6). Remittance inflows must equal the corresponding remittance outflows in world currency units (Equations H4, H5, and H6). Similar to tax instruments, Equation H7 provides a standardised instrument to adjust the share of remittances sent abroad. Hence, $remrYHF0_{w,h,r}$ is the base solution, bilateral remittance rates $dabrrh_{w,h,r}$ are absolute changes in the base remittance rates, $REMADJ_r$ are multiplicative adjustment factors, $DREM_r$ are additive adjustment factors, and

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

$remrYHF01_{h,r}$ is a matrix of zero and non-zero values that determines for which households and region pairs the remittance rates can adjust additively.

72. Household consumption demand is derived in two stages. In the first stage (Equation H8), disposable household income ($YHD_{h,r}$) is defined as household factor incomes after payment of direct taxes and inter-household transfers (net remittance flows). Second, household consumption expenditures ($HEXP_{h,r}$) are defined as disposable income after savings (Equation H9). Saving rates are defined as proportions of disposable household income; this is important for the calibration of the income tax and savings parameters.

	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Household block			
(H1)	$YHEQ_{h,r}$	$YH_{h,r} = \sum_f (hvash_{h,f,r} * YFDIST_{f,r}) + \sum_{wgn} REMIN_{h,wgn,r}$	(h*rgn)	$YH_{h,r}$	No
(H2)	$YHFEQ_{h,r}$	$YHF_{h,r} = \sum_f (hvash_{h,f,r} * YFDIST_{f,r})$	(h*rgn)	$YHF_{h,r}$	No
(H3)	$REMOUTEQ_{w,h,r}$	$REMOUT_{w,h,r} = REMRYHF_{w,h,r} * YHF_{h,r} * (1 - TYH_{h,r})$	(w*h*rgn)	$REMOUT_{w,h,r}$	No
(H4)	$REMOUTWEQ_{w,h,r}$	$REMOUT_{w,h,r} = REMOUTW_{w,h,r} * ER_r$	(w*h*rgn)	$REMOUTW_{w,h,r}$	No
(H5)	$REMINWEQ_{h,w,r}$	$REMINW_{h,w,r} = REMOUTW_{w,h,r} \quad \forall\, map\_w\_r$	(h*w*rgn)	$REMINW_{h,w,r}$	No
(H6)	$REMINEQ_{h,w,r}$	$REMIN_{h,w,r} = REMINW_{h,w,r} * ER_r$	(h*w*rgn)	$REMIN_{h,w,r}$	No
(H7)	$REMRYHFDEF_{w,h,r}$	$REMRYHF_{w,h,r} = (remrYHF0_{w,h,r} + dabrrh_{w,h,r}) * REMADJ_r + DREM_r * remrYHF01_{w,h,r}$	(w*h*rgn)	$REMRYHF_{w,h,r}$	No
(H8)	$YHDEQ_{h,r}$	$YHD_{h,r} = YHF_{h,r} * (1 - TYH_{h,r}) + \sum_w REMIN_{h,w,r} - \sum_w REMOUT_{h,w,r}$	(h*rgn)	$YHD_{h,r}$	No
(H9)	$HEXPEQ_{h,r}$	$HEXP_{h,r} = YHD_{h,r} * (1 - SHH_{h,r})$	(h*rgn)	$HEXP_{h,r}$	No
(H10)	$QCDEQ_{c,h,r}$	$PCD_{c,r} * QCD_{c,h,r}(1 + TV_{c,r}) = (PCD_{c,r} * qcdconst_{c,h,r}(1 + TV_{c,r})) + beta_{c,h,r} * \left[HEXP_{h,r} - \sum_c (PCD_{c,r} * qcdconst_{c,h,r}(1 + TV_{c,r}))\right]$	(c*h*rgn)	$QCD_{c,h,r}$	No

73. The household utility functions are assumed to be Stone-Geary, i.e. a linear expenditure system. This 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 (Equation H10). 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 to the Frisch parameter if the elasticity of the marginal utility of income is also set to one. An 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.

Government taxes

74. There are nine tax instruments. Eight are defined as a simple *ad valorem* rate dependent on 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 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* by region *r* in the base solution.

75. The tax rate equations allows the tax rates to vary 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.

76. In the import tariff rate equation (Equation T1.1) $tmb_{w,c,u,r}$ 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, $TMADJ_r$ 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 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.

- 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 equiproportionate change in the import duty rates necessary to satisfy model constraints. For example, if $TMADJ_r$ equals 1.1, then all applied (non-zero) import duty rates (found in the base data) for the specified region are increased by 10%.
- If any element of $dabtm_{w,c,u,r}$ is not zero, and all other initial conditions hold, then an absolute change in the initial import tariff rate for the relevant commodity is imposed. For example, 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%).
- If $TMADJ_r$ for one region is made a variable which requires the fixing of another variable for that region and 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. $tm0_{w,c,u,r}+dabtm_{w,c,u,r}$ (these applied rates can be different from those in the base where $dabtm_{w,c,u,r}$ is set to zero).
- 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 1, 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. For example, if food products are excluded from the change in tax rates, then the elements of $tm01_{w,c,u,r}$ corresponding to the food commodities are (left as) zero. It is necessary in this case to both 'free' a variable and to give values to a parameter for a solution to emerge. If the change in the applied tax rates is other than equiproportionate, then values of $tm01_{w,c,u,r}$ other than one can be applied. For example, if the changes in the import duties on food products are half those of 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, they can be set to 1.

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

77. This combination of alternative adjustment methods covers the range of common tax rate adjustments used in the majority of applications while being flexible and easy to use. Experience has shown, however, 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, several 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 odd results.

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

79. The government tax revenue equations sum the revenues from the 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 Equation G1). However, it is useful to carry these additional variables since they can then be used in model

closures to accommodate specific government tax revenue objectives. They are also useful sources of information when analysing simulation results.[24]

80. Import duty revenues ($MTAX_r$) are defined as total import duty revenue in region *r* (Equation T2.1); specific Import duty revenues ($MSTAX_r$) are defined as total specific import duty revenues in region *r* (Equation T2.2); export tax revenues ($ETAX_r$) are defined as total export tax revenue in region *r* (Equation T2.3); sales tax revenues ($STAX_r$) are defined as total sales tax revenue in region *r* (Equation T2.4); VAT revenues ($VATAX_r$) are defined as total VAT revenue in region *r* (Equation T2.5); production tax revenues ($ITAX_r$) are defined as total production tax revenue in region *r* (Equation T2.6); factor income tax revenues ($FYTAX_r$) are defined as total factor income tax revenue in region *r* (Equation T2.7); household income tax revenues ($HTAX_r$) are defined as total household income tax revenue in region *r* (Equation T2.8); and factor use tax revenues ($FTAX_r$) are defined as total factor use tax revenue in region *r* (Equation T2.9).

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

[24] It is easy 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 a variable such aggregates that may have substantive benefits in terms of transparency and simulation formulation.

Government

81. Government income (YG_r) is defined as the sum of government tax revenues (Equation 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. There is no provision for government to receive incomes form non-tax sources in this version, which reflects the fact that no such incomes are recorded in the GTAP database.

82. Government demand for commodities (Equation 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 on the choice of closure rule (see below). Thereafter, government consumption expenditure (EG_r) is defined as the sum of commodity consumption valued at the appropriate price (Equation G3). The advantage of expressing separately 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 the volume, 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

83. 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 ($KAPWOR_r$). This is defined as the sum of savings by domestic and 'foreign' agents (Equation K3). In this model, the household savings rates are declared as variables ($SHH_{h,r}$) that define the proportion of income saved after payment of income taxes. The savings rate equation (Equation K1) uses 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 (Equation K2).

84. Government savings are calculated as a residual (see the $KAPGOV_r$ equation, Equation MC2.9). The surplus on the capital account ($KAPWOR_r$) is defined in terms of the foreign currency (see Equations MC2.11 and MC2.12) and therefore the exchange rate appears in this equation.

85. A regional savings rate, including both household and government savings, is defined as share of the sum of disposable household income and government income

(Equation K6). Regional savings are the sum of household and government savings. The regional savings rate can be used in the closure setup.

86. Investment demand (Equation K4), that is demand for commodities 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 total value of investment ($INVEST_r$) is calculated by summing across commodities and valuing the price for investment goods (Equation K5). This arrangement allows adjustment of investment demand through the volume, the expenditure, or the value share in final demand (see below).

	Name	Equation	Number of Eq. and Var.	Variable	Globe Region
		Capital Block			
(K1)	$SHHDEF_{h,r}$	$SHH_{h,r} = (shh0_{h,r} + dabshh_{h,r}) * SADJ_r + DSHH_r * shh01_{h,r}$	(h*rgn)	$SHH_{h,r}$	No
(K2)	$HHLDSAVEQ_{h,r}$	$HHLDSAV_{h,r} = YHD_{h,r} * SHH_{h,r}$	(h*rgn)	$HHLDSAV_{h,r}$	No
(K3)	$TOTSAVEQ_r$	$TOTSAV_r = \sum_h HHLDSAV_{h,r} + \sum_f (deprec_{f,r} * YF_{f,r}) + KAPGOV_r + KAPWOR_r * ER_r$	(rgn)	$TOTSAV_r$	No
(K4)	$QINVDEQ_{c,r}$	$QINVD_{c,r} = IADJ_r * qinvdconst_{c,r}$	(c*rgn)	$QINVD_{c,r}$	No
(K5)	$INVESTEQ_r$	$INVEST_r = \sum_c (PINVD_{c,r} * QINVD_{c,r})$	(rgn)	$INVEST_r$	No
(K6)	$SREGHDEF_r$	$\sum_h HHLDSAV_{h,r} + KAPGOV_r = SREGH_r * (\sum_h YHD_{h,r} + YG_r)$	(rgn)	$SREGH_r$	No

1.3.6. Trade and transport margins: The Globe region[25]

87. 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 highlight effects on global transport margins.

88. Figure 6 illustrates the price system for the Globe region. 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

[25] This section is largely identical to McDonald et al. (2013).

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.

89. The export side is slightly different as the Globe region operates as a way to pool differentiated commodities used in trade and transport services. 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 at the same price. Hence, the export price system for Globe needs to be arranged so that it 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 ($PER_{c,u,w,r}$), which should equal the export price in world currency units ($PWE_{c,u,w,r}$) and will be common across all destinations ($PT_{c,u,r}$) (Equation MC1.1).

90. The linked quantity system contains the same asymmetry in the treatment of imports and exports by Globe (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 thus the elasticities of transformation are infinite.

91. One consequence of using a Globe region for trade and transport services is that it 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. 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 have only an indirect effect on their demand; the only area 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 (Equation MC1.2).

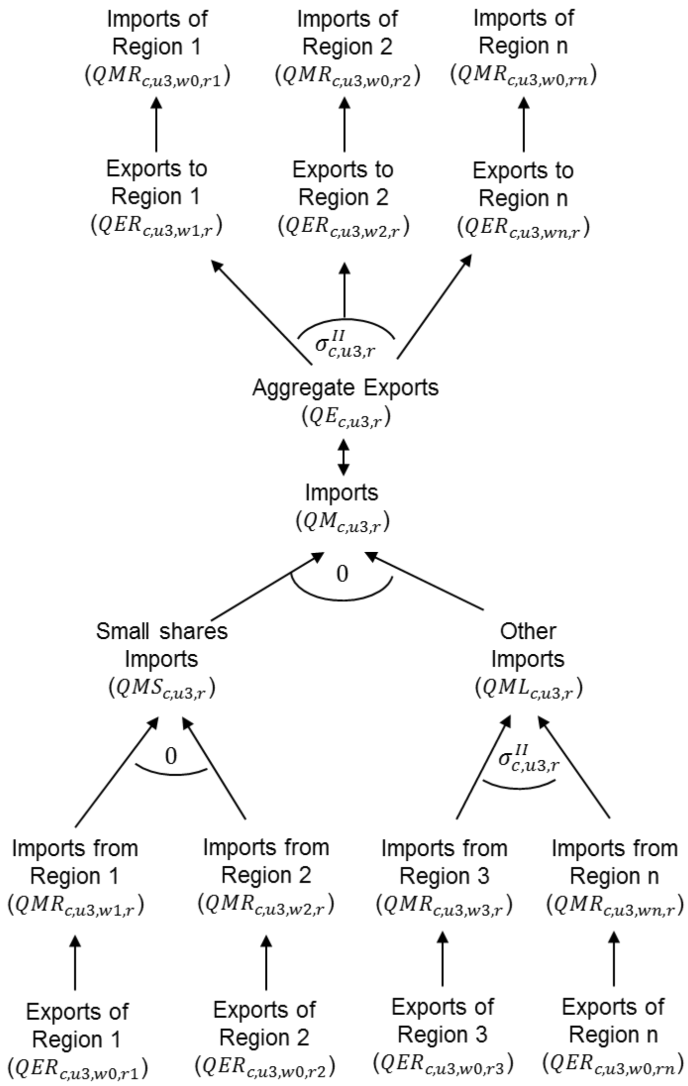
92. The Globe concept has other potential uses. All transactions between regions for which there is an absence of full bilateral information can be routed through the Globe region. While this is not a 'first best' solution, it does provide a 'second best' method by which augmented versions of the GTAP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

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

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

94. There is no separate equilibrium condition for the supply of domestic output to the domestic market. In fact, activities are transformed into commodities and thus market clearing of domestically-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 (Equation MC2.1). This stock of unemployed factors is positive or zero (Equation F3).

	Name	Equation	Number of Eq. and Var.	Variable	Globe Reg.
		Market Clearing Block			
(MC2.1)	$FMEQUIL_{f,r}$	$FS_{f,r} = \sum_{a} FD_{f,a,r} + UNEMP_{f,r}$ Where *f* is a perfectly mobile factor (f_closure=1).	(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)	$KAPREQUIL_{w,r}$	$KAPREG_{w,r} = \sum_{c,u}(PWMFOB_{w,c,u,r} * QMR_{w,c,u,r}) - \sum_{c,u}(PWE_{c,u,w,r} * QER_{c,u,w,r}) + \sum_{h} REMOUTW_{w,h,r} - \sum_{h} REMINW_{h,w,r}$	(wgn*r)	$KAPREG_{w,r}$	Yes
(MC2.11)	$KAPREQUIL2_{w,r}$	$KAPREG_{w,r} = \sum_{c,u}(PT_{w,c,"uint",r} * QT_{w,c,u,r}) - \sum_{c,u}(PWE_{c,u,w,r} * QER_{c,u,w,r})$	(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)	$SYSEQUIL_{r}$	$KAPWORSYS = \sum_{rgn} KAPWOR_{rgn}$	(1)	$KAPWORSYS$	No

95. In the commodity markets, the domestic and import supply is equal to the domestic demand of that commodity for intermediate, household, government, or investment use (Equations MC2.2 to 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 (Equation 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 (Equation 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 by Equation 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. Similar conditions apply for the margins trade (Equations MC1.1 and MC1.2).

96. Government savings ($KAPGOV_r$) clear the government accounts, which is the residual of government income and government expenditure (Equation 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 (Equation MC2.10) and then for trade between Globe and all other regions (Equation MC2.11), the latter being the trade balances on margins trade. These transactions are valued in terms of the global numéraire. The overall balance of trade ($KAPWOR_r$) is then computed for each region (Equation MC2.12).

97. 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 the slack variable $WALRAS_r$ should equal zero in Equation MC2.13. That this variable equals zero is a good way to check on the correct specification of the model. Finally, as the global trade balance must be zero, so must *KAPWORSYS* (Equation MC2.14).

1.4. Model closure conditions[26,27]

98. In mathematical terms, the model closure conditions are, at their simplest, a matter of ensuring that the number of equations and variables are consistent. However, the economic theoretical 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).

99. The closure rules can be perceived as operating on two levels. On a general level they relate to macroeconomic considerations, e.g. is investment expenditure determined by the volume of savings or exogenously? On a specific level, they are used to capture particular features of an economic system, e.g. the degree of intersectoral capital mobility.

100. METRO allows for a range of general and specific closure rules. The discussion below provides details of several options that are available by reference to the accounts to which the rules refer. However, as will become apparent, there are many permutations and as such this discussion deals only with the general principles. 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

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

[27] The term ‘model closure’ is used generically here to cover all permutations, including variations in market clearing conditions and macroeconomic closure conditions.

policy simulations while simultaneously allowing sensitivity testing of the chosen model closures.

1.4.1. Absorption block

101. 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 and non-household agents' expenditure shares (Equations 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 contains a useful equation for calculation of GDP from value added (Equation 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. $HEXP_r$ could be fixed for individual households if there was a good reason to do so.

	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)	$VGDSHEQ_r$	$VGDSH_r * VFDOMD_r = \sum_c (PGD_{c,r} * QGD_{c,r})$	(rgn)	$VGDSH_r$	No
(MC3.4)	$GDPEQ_r$	$GDP_r = \sum_c \left[\sum_h \left(PCD_{c,r} * QCD_{c,h,r} * (1 + TV_{c,r})\right) + PGD_{c,r} * QGD_{c,r} + PINVD_{c,r} * QINVD_{c,r}\right] + \sum_{w,c,u} (PWE_{c,u,w,r} * ER_{,r} * QER_{c,u,w,r}) - \sum_{c,u,w} (PWM_{w,c,u,r} * ER_{,r} * QMR_{w,c,u,r})$	(rgn)	GDP_r	No

1.4.2. Foreign exchange account closure

102. 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.[28] At the same time, the exchange rate for Globe is fixed as equal to the world numéraire.

103. 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

[28] In the base and model simulations, *numerchk* equals one. This 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.

balance is fixed and the exchange rate floating. There is clearly a range of permutations whereby the exchange rates for some regions are flexible and for others fixed.

	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		$KAPWORSYS = \overline{KAPWORSYS0} = 0$

1.4.3. Capital account closure

104. For the capital account closure, savings can either be investment driven or investment is savings driven. When investment is savings driven, savings are to be fixed (neo-classical approach); there is the choice to fix the regional savings rate (government and household combined) or the private saving rates adjuster (multiplicative) and investment is 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 be adjusted by changes in the savings rate, and one of the saving rates adjusters are made flexible.

105. There are, however, potentially important interaction effects as there are other sources of potential savings for region, i.e. the government and the trade balances. The magnitudes of these other sources of savings can be controlled through the closure rules (see below). There are clearly important interdependencies between the choices of closure rules for different accounts, the most obvious being 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	The regional savings rate or the private savings rate is fixed $SREGH_r = \overline{SREGH_r}$ or $SADJ_r = \overline{SADJ_r}$	$IADJ_r = \pm\infty$ $INVEST_r = \pm\infty$ $INVESTSH_r = \pm\infty$
or	Investment driven savings	The savings rate adjuster and the regional savings rate become flexible.	One is fixed, two stay variable: $IADJ_{rgn} = \overline{IADJ_{rgn}}$ or $INVEST_r = \overline{INVEST_r}$ or $INVESTSH_r = \overline{INVESTSH_r}$

1.4.4. Government account closure

106. The closure of the government account specifies how government income and expenditure (and the balance of the two), the 'internal balance' or government (dis-) savings are all determined. Two of the three variables must be fixed in the closure, while the third can be adjusted freely. In the preferred base specification, the internal balance is fixed so that the government does not accumulate a deficit or save more when some policies

change. Government income is determined by the accounting Equations T2.1 to T2.9. When all tax rates are fixed this implies that government income cannot vary freely. That leaves government expenditure as a variable to move freely in the base specification. If one of the fixed components of the government account is made flexible, another component must be fixed. For example, one tax rate could be made flexible so that government income can adjust freely, while still maintaining the internal balance at base levels. To make tax rates flexible, endogenous multiplicative or additive scaling factors are used that shift the base rates. With income flexible, government expenditures must be fixed to maintain the internal balance at base level. This can be done by pinning down 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 ($VGDSH_r$).

107. The number of possible permutations for closing the government account for each region is substantial and can be used to explore the implications of government budgetary decisions when other policies change. Practical experience indicates that great care is needed when adjusting government closure rules to avoid unbalancing the model or imposing closure rules that are contradictory.[29]

	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.

108. As with the investment account, care is also needed when 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

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

tax rates are exogenous. The same applies if the shares of government expenditures in final demand ($VGDSH_r$) are fixed.

1.4.5. Technology and efficiency

109. 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 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.

1.4.6. Numéraire

110. 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 serve as a base reference 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	$CPI_r = \pm\infty$	$PPI_r = \overline{PPI_r} * numerchk$

1.4.7. Factor market closure

111. There are several possibilities to specify factor markets for each region. Factors can be fully employed and mobile[30] or fully employed and immobile across activities. Factors can be unemployed or there could be restrictions originating from factor demand. Lastly, factors can be imperfectly mobile across activities.[31]

112. For perfectly mobile or perfectly immobile factor markets, the closure specifications are determined by the interplay of factor supply ($FS_{f,r}$), regional factor prices ($WF_{f,r}$), sectoral factor prices ($WFD_{f,a,r}$), and factor demand ($FD_{f,a,r}$). For long-term projections, factors are typically assumed to be mobile and fully employed; the factor price is flexible and factor supply fixed. For short-term projections, factors might become immobile across activities, i.e. capital, and therefore factor demand is fixed. For this

[30] Factor market mobility is controlled by the parameter $f\_closure_{f,r}$ where a value of 0 indicates that factors are immobile between activities. A value of 1 indicates full factor mobility and a value of 2 indicates imperfect mobility.

[31] Requires activation of the Land Allocation Module.

specification, the sectoral factor price needs to be adjusted to clear the factor market. With fixed factor demand, the factor supply is also fixed. Thus, the condition that fixes factor supply becomes redundant and needs to be relaxed.

113. Unemployment can be introduced in the equation system with related variables and equations (Equations F3 and MC2.1) or via a specification of the factor market clearing. In the first case, the closure specification is similar to when factors are fully employed and mobile except that there is a lower bound placed on the regional factor price ($WF_{f,r}$). While there are unemployed factors, the factor price remains unchanged until all unemployed factors are used, at which point factor supply is fixed and factor prices becomes flexible.

114. In the second case, factor supply is set perfectly elastic and factor prices are fixed. In case the factor supply might increase unrealistically in simulations, it is possible to include an upper bound on factor supply. The variable is no longer free and its factor price 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 ($WFDIST_{f,activ,r}$).

115. For imperfectly mobile factor markets, the factor supply and factor price are determined in a multi-tiered nesting structure (OECD, 2019). Accordingly, the regional factor price ($WF_{f,r}$) and the total factor supply ($FS_{f,r}$) for imperfectly mobile factors are fixed to zero. The root aggregate factor supply is fixed to its calibrated value, while the factor supply at other levels of the nest, as well as factor prices at all levels, are flexible.

	Factor Account Closure		
	Factors fully employed and mobile	$FS_{f,r} = \overline{FS_{f,r}}$ $FD_{f,a,r} = \pm\infty$	$WF_{f,r} = \pm\infty$ [32] $WFD_{f,a,r} = \pm\infty$ $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$
or	Factors fully employed and immobile (implemented for a single factor or all factors)	$FS_{f,r} = 0$ $FD_{f,a,r} = \overline{FD_{f,a,r}}$	$WF_{f,r} = 0$ $WFD_{f,a,r} = \pm\infty$ $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$
or	Factors fully employed and imperfectly mobile (implemented only for land in METRO version 3)	$FS_{f,r} = 0$ $FD_{f,a,r} = \overline{FD_{f,a,r}}$	$WF_{f,r} = 0$ $WFD_{f,a,r} = \pm\infty$ $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$
		$FS\_CET1_{f,af,r} = \overline{FS\_CET1_{f,af,r}}$ $FS\_CET2_{f,af,r} = \pm\infty$ $FS\_CET3_{f,af,r} = \pm\infty$ $FS\_CET4_{f,af,r} = \pm\infty$	$WF\_CET1_{f,af,r} = \pm\infty$ $WF\_CET2_{f,af,r} = \pm\infty$ $WF\_CET3_{f,af,r} = \pm\infty$ $WF\_CET4_{f,af,r} = \pm\infty$
or	Factors full employed and imperfectly mobile	$FS_{f,r} = 0$ $FD_{f,a,r} = \overline{FD_{f,a,r}}$	$WF_{f,r} = 0$ $WFD_{f,a,r} = \pm\infty$ $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$
or	Unemployment with perfectly elastic supply (implemented for a single factor or all factors)	$FS_{f,r} = \pm\infty$ $FD_{f,a,r} = \pm\infty$	$WF_{f,r} = \overline{WF_{f,r}}$ $WFD_{f,a,r} = \overline{WFD_{f,a,r}} WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$

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

	Factor Account Closure		
or	Unemployment with restricted supply (implemented for a single factor or all factors)	$FS_{f,r} \leq \overline{FS_{f,r}}$ $FD_{f,a,r} = \pm\infty$	$WF_{f,r} = \pm\infty$ $WFD_{f,a,r} = \pm\infty$ $WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$
or	Activity inspired restrictions on factor market closures (implemented for single activities but not all factors)	$FS_{f,r} = \overline{FS_{f,r}}$ $FD_{f,a,r} = \pm\infty$ $FD_{f,activ,r} = \overline{FD_{f,activ,r}}$	$WF_{f,r} = \pm\infty$ $WFD_{f,a,r} = \pm\infty WFDIST_{f,a,r} = \overline{WFDIST_{f,a,r}}$ $WFDIST_{f,activ,r} = \pm\infty$

2. The METRO database

2.1. The METRO-SAM database, v10L14

116. This section describes the METRO-Social Accounting Matrix (SAM) database and its construction. It is derived from the GTAP V10L14 database (see Aguiar et al., 2019) extended with trade flows disaggregates by use categories derived from OECD and UN sources. Bilateral remittance information from the GTAP satellite data GMIG2 (Walmsley et al., 2007) is also included. The METRO database is in a SAM format and developed from a SAM version[33] of the underlying GTAP database. The original GTAP database distinguishes 65 sectors in GTAP classification and 141 regions.

117. The METRO-SAM has been developed using detailed information from OECD and UN sources in order to distribute imports and taxes by source and uses. Hence, imports in the METRO-SAM database (and by default exports) are differentiated according to four categories:

- intermediate use
- private consumption
- government consumption
- investment consumption.

118. Tariffs, export and sales taxes, and margins are differentiated by use.[34] Accordingly, the commodity account identifies the use of imported and domestic goods. This split is based on OECD and UN trade data on use categories of imports and exports, as opposed to the widely applied proportionality assumption.[35]

119. Two sources of information and a set of correspondence tables are used to split the trade flows into use categories. UN Comtrade is used to calculate split shares for the 42 agriculture and manufacturing sectors, and the OECD Inter-Country Input-Output Model (OECD-ICIO, 2018) provides use information for the 16 services sectors.[36] The

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

[34] In the first two versions of the METRO database, tax and tariff rates remain the same across users but future developments will include differentiation of these accounts.

[35] While the proportionality assumption was applied in the development of the OECD-ICIO trade database, it was combined with additional detailed country and sector specific information which made the final statistics more robust.

[36] UN Comtrade rather than the ICIO is used to preserve the detail in the agriculture sector since there is only one agriculture category in the ICIO database (Agriculture, hunting, forestry, and

OECD ICIO data, however, is available only for a subset set of countries. Accordingly, the 141 regions in GTAP are aggregated to match the 65 regions available in the OECD database.[37] Table 8 lists regions and sectors depicted in the METRO-database and Table 9 shows the structure of a regional SAM of the METRO-SAM database which distinguishes 65 regions, 65 sectors and 4 use-categories.

120. Similar to an input-output table (IO-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, e.g. private import consumption is displayed as an expenditure of the household account and income in the commodity account. The focus of an IO-Table lies in the transactions concerning domestic production, its formation, and its use. The SAM approach goes further and aims to incorporate all transactions in an economy at a given point in time, especially those between households, government and primary factors. The SAM methodology represents a complete characterisation of the current account transactions of an economy as a circular system and is completely embedded in the UN System of National Accounts.[38] It is thus possible to follow income flows throughout the system and identify the 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 into the trade relationships, where each export value of one region must have an identical counterpart in imports to another region or regions.

fishing). OECD-ICIO information is required because UN Comtrade does not cover trade in services.

[37] See Annex A for the sectors and regions mapping between GTAP and OECD-ICIO.

[38] http://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf.

Table 8. Countries and sectors in the METRO database

Regions				Sectors			
arg	Argentina	ltu	Lithuania	pdr	Paddy rice	bph	Basic pharma products
aus	Australia	lux	Luxembourg	wht	Wheat	rpp	Rubber and plastic products
aut	Austria	mys	Malaysia	gro	Cereal grains nec	nmm	Mineral products nec
bel	Belgium	mlt	Malta	v_f	Vegetables, fruit, nuts	i_s	Ferrous metals
bra	Brazil	mex	Mexico	osd	Oilseeds	nfm	Metals nec
brn	Brunei	mar	Morocco	c_b	Sugar cane, sugar beet	fmp	Metal products
bgr	Bulgaria	nld	Netherlands	pfb	Plant-based fibers	ele	Computer, elect & optical
khm	Cambodia	nzl	New Zealand	ocr	Crops nec	eeq	Electrical equipment
can	Canada	nor	Norway	ctl	Bovine cattle, sheep & goats, horses	ome	Machinery & equipment nec
chl	Chile	per	Peru	oap	Animal products nec	mvh	Motor vehicles and parts
chn	China	phl	Philippines	rmk	Raw milk	otn	Transport equipment nec
col	Colombia	pol	Poland	wol	Wool, silk-worm cocoons	omf	Manufactures nec
cri	Costa Rica	prt	Portugal	frs	Forestry	ely	Electricity
hrv	Croatia	rou	Romania	fsh	Fishing	gdt	Gas manufacture, distrib
cyp	Cyprus	rus	Russian Federation	coa	Coal	wtr	Water
cze	Czech Republic	sau	Saudi Arabia	oil	Oil	cns	Construction
dnk	Denmark	sgp	Singapore	gas	Gas	trd	Trade
est	Estonia	svk	Slovakia	oxt	Other Extraction	afs	Accomm, Food & service
fin	Finland	svn	Slovenia	cmt	Bovine meat products	otp	Transport nec
fra	France	zaf	South Africa	omt	Meat products nec	wtp	Water transport
deu	Germany	esp	Spain	vol	Vegetable oils and fats	atp	Air transport
grc	Greece	swe	Sweden	mil	Dairy products	whs	Warehousing & support act.
hkg	Hong Kong, China	che	Switzerland	pcr	Processed rice	cmn	Communication
hun	Hungary	twn	Chinese Taipei	sgr	Sugar	ofi	Financial services nec
ind	India	tha	Thailand	ofd	Food products nec	ins	Insurance
idn	Indonesia	tun	Tunisia	b_t	Beverages & tobacco products	rsa	Real estate activities
irl	Ireland	tur	Turkey	tex	Textiles	obs	Business services nec
isr	Israel	gbr	United Kingdom	wap	Wearing apparel	ros	Recreational & other services
ita	Italy	usa	United States	lea	Leather products	osg	Public Admin & defense
jpn	Japan	vnm	Viet Nam	lum	Wood products	edu	Education
kaz	Kazakhstan	row	Rest of the World	ppp	Paper products, publishing	hht	Human health & social work
kor	Korea			p_c	Petroleum, coal products	dwe	Dwellings
lva	Latvia			chm	Chemical products		

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.
c) This table does not include the Globe region (see Section 1.3.6).
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.

121. 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, the so-called activities, use domestic and imported commodities as intermediate inputs. Households, government and the capital account use commodities for private, government and investment consumption, respectively.

122. Exports are displayed as purchases by the rest of the world for 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 is distinguished by the respective use category.

123. The total value of domestic commodity supply includes the domestic supply at producer prices. This is 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.

124. 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 and/or allowances, and spends it on capital goods consumption.

125. 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 65 regions, 65 sectors, 4 use-categories, and 8 primary factors. Table 10 shows the dimensions of the METRO-SAM database version 10L14 with a total of 1 756 accounts for each regional matrix. Given the large number of accounts in each region's SAM and the relatively large number of regions, this renders the total number of transaction values in the full database very large, over 3 million, even when considering empty cells.

Table 10. Dimensions of the METRO-SAM database, version 10L14

Account groups	Number of accounts	
Commodities	(2*c)	130
Activities	(a)	65
Factors	(f)	8
Taxes	(2*r*u+1*f+1*u+2)	526
Other domestic institutions	3	3
Margins	(3*r*u)	768
Trade	(r*u)	256
Total number of accounts		1 756
Number of data points in global SAM		3 672 552

Source: Authors' compilation.

126. When the database is large, the size of the model which uses this database will be even larger because each transaction flow is connected to at least two variables: a price and a quantity. The use of a large model is problematic, however, in solver capacity and can be too lengthy in terms of solution time and output. A large model also makes the interpretation of results unnecessarily complex. CGE models designed for the specific study purpose are therefore generally applied with aggregate databases. In this regard, the

size of the database is important in order to provide a reasonable choice of aggregations for the user. Hence, the aggregation of the database is highly recommended for the application of METRO.[39]

2.2. Construction of the METRO-SAM database v10L14

127. The METRO-SAM database v10L14 is based on an augmented SAM version of the GTAP database (McDonald and Thierfelder, 2004). Its construction follows three steps. The first step consists of generating use shares for commodity imports (and exports), which are then used to split the trade matrices. Based on this split, the SAM is rearranged into the new METRO-SAM format in a second step. The third step consists of making final corrections to achieve a balanced SAM.

2.2.1. Generating a full dataset of use shares

128. The use shares which are used to split trade flows by use category (intermediate, household, government, and investment consumption) are based on several data files: two data files which originate from data underlying the OECD-ICIO tables and UN Comtrade, along with correspondence tables that map HS codes to GTAP sectors and uses. The use shares for the service sectors are derived by applying a set of conversion keys that have been estimated using the classification correspondence tables developed by the OECD Directorate for Science Technology and Industry, as well as the available classification correspondence tables published by the UN statistical division (UNSD)[40]. The remaining sectors rely on UN Comtrade data and two correspondence tables. From World Integrated Trade Solutions (WITS), the correspondence Table H0 to GTAP classifies HS codes to GTAP sector number. The OECD conversion key, the Bilateral Trade in Goods by Industry End-use Category, classifies the HS codes into end-use.

- Bilateral export shares for *services sectors* are available for 64 regions, 16 OECD-ICIO sectors, which correspond to 19 aggregate GTAP sectors, and 4 use categories.
- Data on *manufacturing and agricultural sectors* was supplied with bilateral import and export market shares based on UN Comtrade, and are available for 173 regions, 46 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.

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

- *Country coverage*: The base GTAP-SAM database identifies 141 regions, compared to 173 and 64 regions in the manufacturing/agricultural and services use-shares data, respectively. The use shares are applied to the 64 regions which are identified in all three databases. For regions where no use shares are available, we assume proportionality across uses (Annex Table A2).

[39] An aggregation of 11 commodities and sectors and 18 regions has over 1.6 million of variables to be analysed.

[40] The BDTIxE documentation provides details of the split process. See also http://www.oecd.org/sti/ind/49894138.pdf.

- *Sector classification*: The base SAM distinguishes 65 GTAP sectors, while use shares for manufacturing and agriculture are provided in GTAP format for 46 sectors. Sectors 1 to 45 are applied directly, while GTAP 46 is a services sector to which the OECD services use shares are applied. Services use shares are provided for 16 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 four use categories of interest: (1) intermediate use, (2) private consumption, (3) government consumption and (4) investment consumption. Manufacturing/agricultural use-shares are provided in five 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 17% of total trade flows, are singled out because this category contains data on all four use categories. The mixed-use category includes items such as 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.

130. 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 the People's Republic of China (hereafter "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 44% of all use-shares in the final 65 regions are imputed.

2.2.2. Rearranging the SAM

131. The complete set of use shares is applied to split the trade flows by use. Thus, the import and export matrices become four dimensional, reflecting bilateral trade flows by commodity and use category. 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, assuming equal rates over use categories for import tariffs, export taxes and sales taxes.[41] Trade and transport margins are assumed to be the same for all use categories.

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

[41] Currently, tax and tariff rates remain the same across users but future development of the database will differentiate these accounts.

2.2.3. Correction of anomalous entries

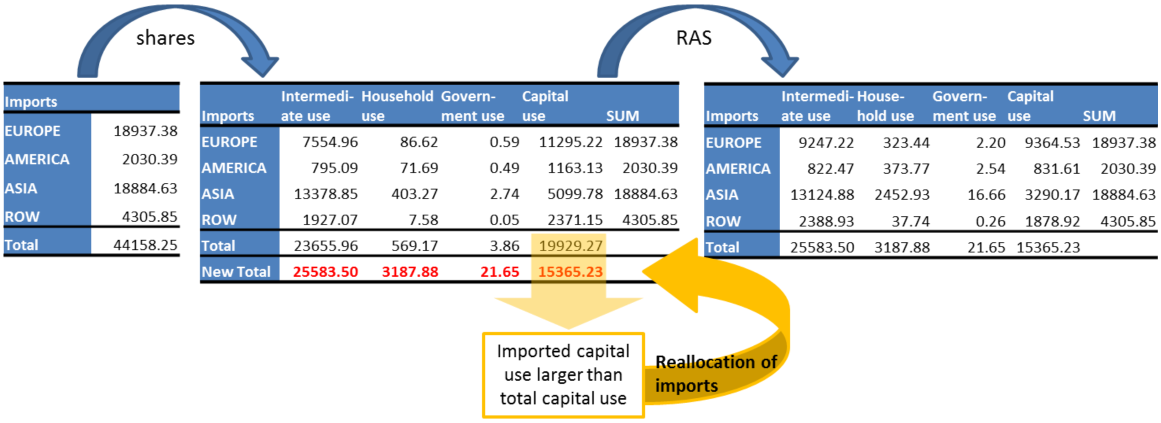
133. Import demand by use is defined by the OECD shares data, which are applied to the GTAP databased SAM. The total sum of imports over all uses stays the same, but the distribution of imports over uses is a new feature. The merger of the two different datasets, which do not necessarily perfectly fit 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, thereby implying a negative value for domestic rice demand. In order to correct for such erroneous entries, the use shares are adjusted to meet the overall constraints of the underlying SAM database. This approach maintains the adjustment process solely within the new information introduced, while maintaining the integrity of the underlying SAM.

134. For those entries showing anomalous outcomes (about 10% of total use entries in the new database), imports are redistributed amongst the 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 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. The close relation of final consumption of government and households as well as intermediate inputs and investment consumption is thus recognized. This is also reflected in the creation of the use-shares. In a second step the remaining surplus is redistributed proportionally over all uses and, in the final step, additionally over uses.

135. 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 shows the process as a numerical example for imports of Russian motor vehicles. 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, this is displayed in Figure 8 as a negative domestic use of capital goods, imports are reallocated among uses as described in the above paragraph.

136. The reallocation leaves the import matrix with new column totals while maintaining the row sums. The matrix is rebalanced by applying the RAS matrix balancing method; the right table in Figure 8 shows the import matrix containing the new use shares. This procedure balances a series of matrices where row and column sums are known and coefficients need to be adjusted. For this kind of problem, the RAS methodology is the most appropriate (Robinson et al. 2001). In cases where RAS cannot solve the problem because the difference between the initial and final distribution is too large, i.e. because of the number of zeroes, the initial distribution is adjusted.

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



Imports	
EUROPE	18937.38
AMERICA	2030.39
ASIA	18884.63
ROW	4305.85
Total	44158.25

Imports	Intermedi-ate use	Household use	Govern-ment 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	Intermedi-ate use	House-hold use	Govern-ment 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

137. 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.

138. Four elasticities relate to trade. These are the first and second level substitution elasticities on both the import and export sides. As a general rule, the second level elasticity is typically larger than the first level. The user can choose to take trade elasticities from the GTAP database, which are based on academic literature. Given the importance of trade elasticities, there have been several studies estimating their parameters.[42] Yet despite these studies, there is 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 by several practical issues. Furthermore, the GTAP database provides elasticities on the import side only and as no other estimates are available, these are also applied on the export side. Alternatively, each trade elasticity can be provided by the user.

139. The model employs a three-level nested CES production process and, as such, 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}). Although elasticities should be user defined, GTAP can be used as the basis for the first two levels.

140. 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 income elasticity are defined by the user.

[42] See Goldstein and Khan (1985), and McDaniel and Balistreri (2003) for reviews of the literature.

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

142. 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. This should be done with a comprehensive sensitivity analysis.

Table 11. Dimensions 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 parameter		
Frisch parameter		User defined
Income		User defined

Source: Authors' compilation.

3. Modules

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

144. There are currently six modules available. The LCR module supplies a policy instrument to depict local content requirements (LCR) in the form of quantitative restrictions. The alternate intermediate nesting identifies activity-specific imports and domestic supply. 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. The Willingness to Pay module, an alternative approach to modelling NTMs. The Capital Accumulation module, which incorporates capital accumulation effects into METRO. And lastly, the land allocation module which allows for better representation of the in production related to land.

145. The LCR, alternate intermediate nesting, and price preferences modules are described below. For the remaining modules, detailed documentation are available as working papers or technical notes:

- OECD (2017), "Metro development: Modelling Non-Tariff Measures and Estimation of Trade Facilitation Impacts", [TAD/TC/WP(2016)20/FINAL].

- Capital Accumulation: Van Tongeren, F. and D. Flaig (2017), "Capital Accumulation in a Comparative Static Model" (Technical note).
- Land Allocation Module: OECD (2019), "Land allocation representation in the METRO model: Technical Documentation" [TAD/TC/CA/WP/RD(2019)4/FINAL].

3.1. Local content requirement (LCR) module

146. Studies of LCR have relied to date on analysing their impact by their effect on prices. They are usually converted to *ad valorem* equivalents or treated as shadow prices. For example, Jensen and Tarr (2008) in an 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 from the gross revenues of multinational oil firms. They find that the elimination of these local content policies results in a gain in welfare that is equal to 0.2% of consumption.

147. The use of *ad valorem* equivalents in the context of LCRs suffers from two major problems. First, there are no estimates on the size of a possible *ad valorem* equivalent. Accordingly, Hufbauer et al. (2013), for example, simply apply an *ad valorem* equivalent of 10%. A second problem, as noted above, LCRs use quantities rather than prices to influence the geographic distribution of purchases. Hence, LCRs are not price instruments, but rather affect the quantity and through quantity, they influence prices. This implies different market adjustment processes. To estimate the effects of these policies an approach based on quantity effects has been developed to include LCRs in a CGE framework.

148. Many LCRs are defined as a percentage share of base supply and are assumed to affect imports only when local content is lower than the import share, making the LCR binding. The underlying assumption is that a company's observed intermediate input use is based on optimal allocation at given prices. LCR will change this input allocation only if prices change or it is required to because of LCR policy. As long as a company is fulfilling the LCR, it is not binding. For example, if the current domestic content in inputs is 60% and the related 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 domestic content in inputs is 40% and the related LCR is 50% – the company must reduce its imports use and increase inputs sourced from domestic production to a minimum of 50%.

149. To capture this reality, domestically-produced supply (*QD*) is modelled for two components (Equation 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 above). The second component is the quantity which is additionally needed to fulfil the LCR (QD^{LCR}) (i.e. 10%)

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

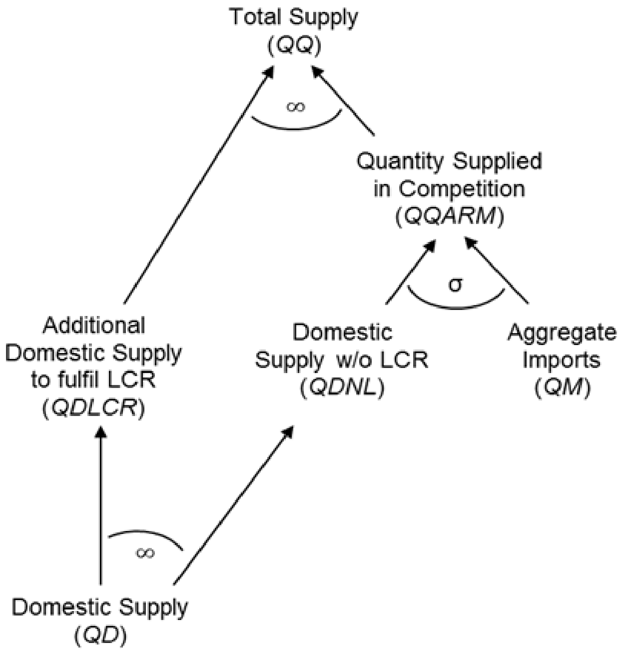
If domestic sources meet or surpass the LCR, $QD = QD^{NL}$.

150. Total supply is likewise broken into two components (Equation 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.

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

151. The share going to fill the LCR is extracted prior to the Armington function because this part of the domestic supply must be supplied domestically irrespective of the relative prices. It is thus not in competition with imports. If an LCR is binding, a part of the total supply is supplied through the LCR channel, which decreases the demand of goods supplied through the Armington nest. Relative prices are adjusted, 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.

152. The Armington equation (Equation LCR-M3) gives the total supply (from imports and domestic sources) under a competitive market. It is an aggregate of the domestic production 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.

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

153. 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 to be homogeneous, irrespective of the channel through which they are supplied.

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

154. The quantity of local content required (*QLCR*) is defined as a share (*lcrshVAR*) of the total supply (Equation LCR-M5a). Where *lcrshVAR* is defined as the share of total supply which must be local content (*lcrsh*) (Equation LCR-M5b), *lcrsh* constitutes the

policy parameter. The module offers the possibility to fix the level of inputs to its base level ($\overline{QM}$): the slack parameter *fiximp* which is typically zero is set to 1.

$$QLCR = (\mathrm{QD} + \mathrm{QM}) * lcrshVAR \quad \text{(LCR-M5a)}$$

$$lcrshVAR = {QD}\Big/{(QD + \overline{QM})} * fiximp + lcrsh \quad \text{(LCR-M5b)}$$

155. The LCR is implemented as a mixed complimentary problem (MCP), with a regime switch between where the LCR is not binding to where it becomes binding. When the LCR is binding, the market itself does not supply the required domestic production (i.e., 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 to the quantity of local content required (*QLCR*) (Equation LCR-M6), hence the slack variable (*s*) is by definition negative or zero (Equation LCR-M7). The slack variable reports the amount of domestic supplied quantity 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

156. The alternate intermediate nesting identifies activity specific imports and domestic supply. This feature is used first (and immediately) for the modelling of 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).

157. 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.

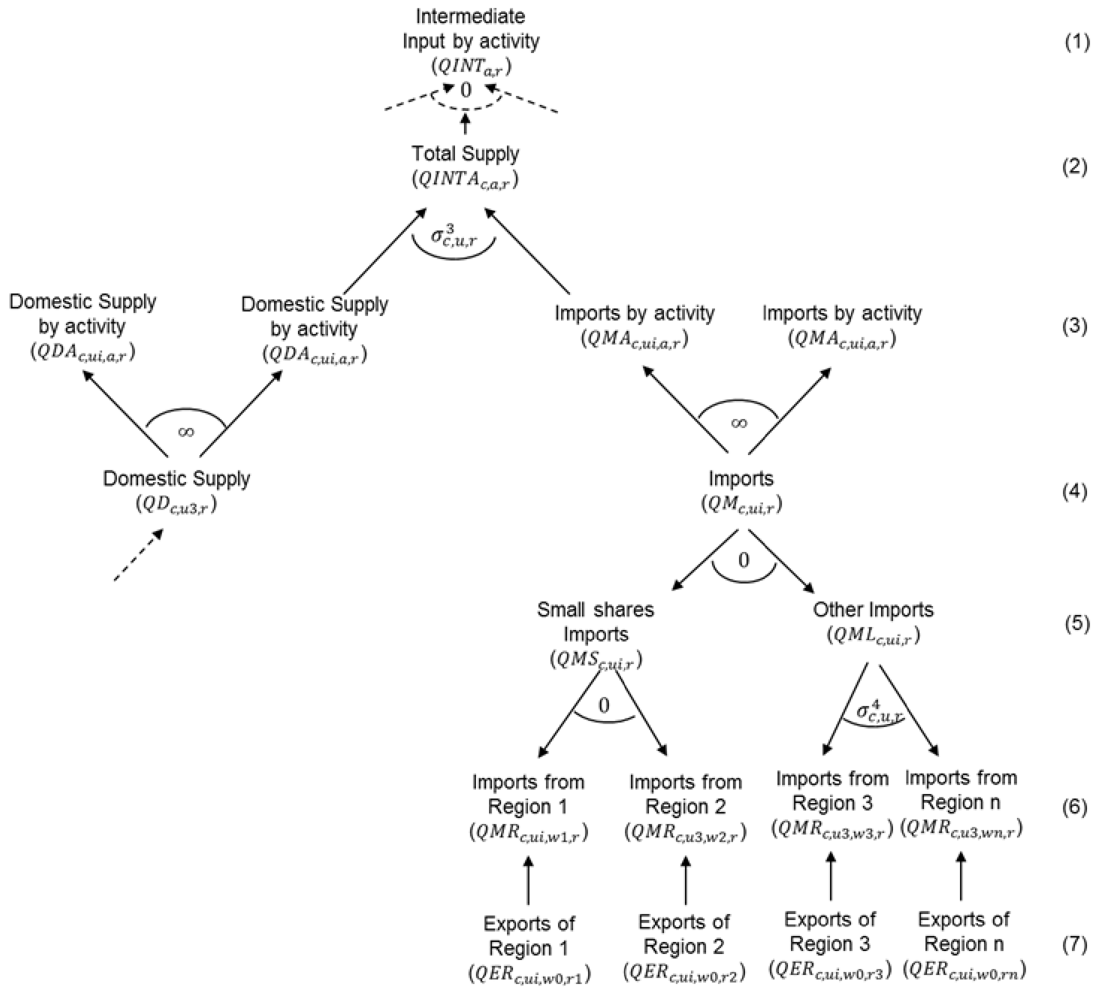
158. Figure 10 shows the relation between quantities and Figure 11 between prices. Following the import branch on the lower right of Figure 10, bilateral imports of commodities *c* for intermediate use *ui* by region *r* are aggregated, thus distinguishing small share imports (Levels 7-4 in Figures 10 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 (Equations 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[43] (Figure 11).

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

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

[43] This assumption can easily been dropped when additional information or new evidence suggests so.

Figure 10. Alternate intermediate input nesting: Quantities



Source: Authors' compilation.

159. In the domestic branch, on the left side 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.

160. Activity specific imports and activity specific domestic supply are aggregated with the Armington equation, forming an aggregate activity and commodity specific intermediate input supply ($QINTA_{c,a,r}$).[44]

[44] As *ui* consists only of one use category, this dimension can 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 $ac\_a_{c,ui,a,r}$ as 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.

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

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

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

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

163. The purchaser price of intermediate inputs ($PINTA_{c,a,r}$) includes the sales tax rate ($tsa_{c,ui,a,r}$).[45]

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

164. Finally, at 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.

165. 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 ($QINTD_{c,r}$).

166. The tax revenue ($STAX_r$) equation is extended to include the sales tax revenue from intermediate input use. [46]

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

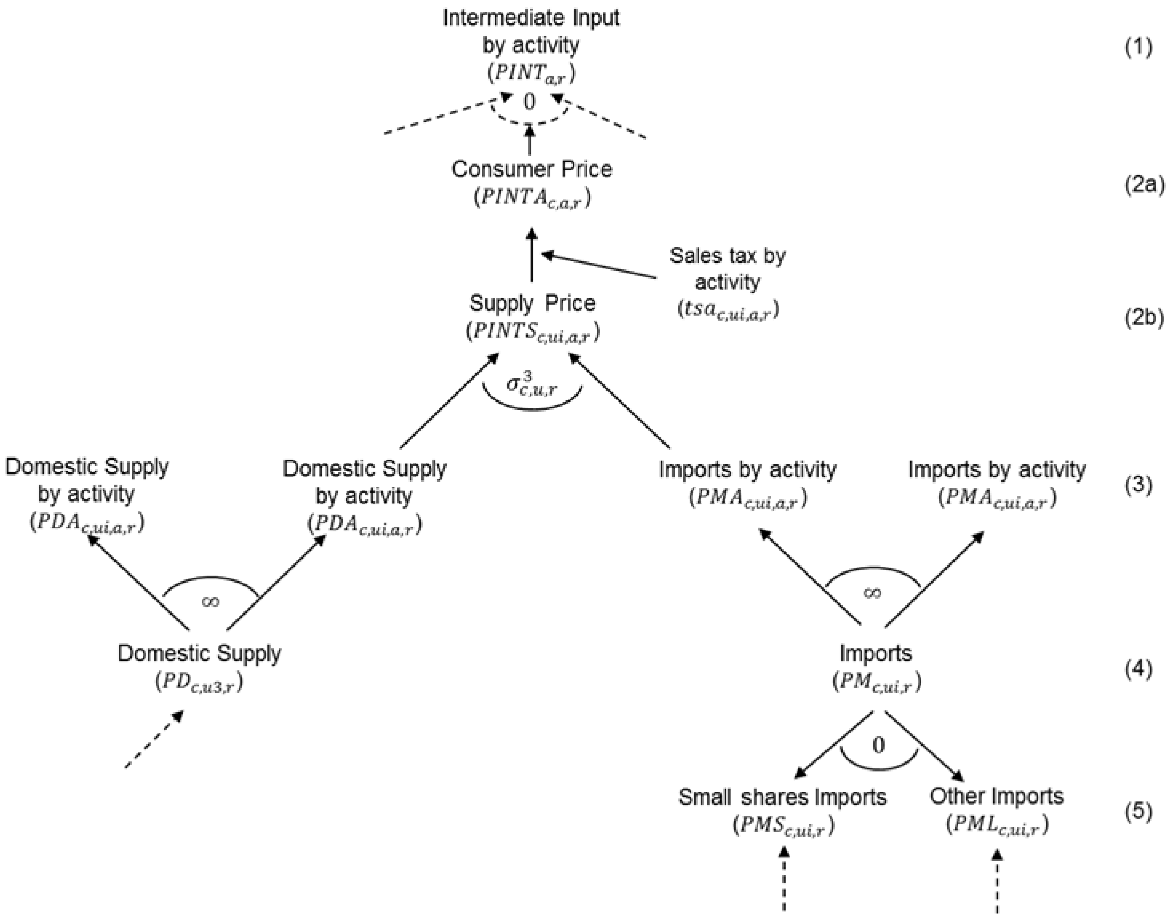
167. Total supply of intermediate inputs ($QQ_{c,ui,r}$) is calculated for the analysis of aggregate intermediate input supply by commodity.

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

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

[46] Again, since set *ui* has only one member, it 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

168. 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 in the domestic supply by activity in the domestic branch between Levels 2 and 3 in Figure 10.

169. 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 LCR share ($lcrsh\_A_{c,a,r}$) is zero in the base situation and the policy instrument which can be shocked in simulations.

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

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

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

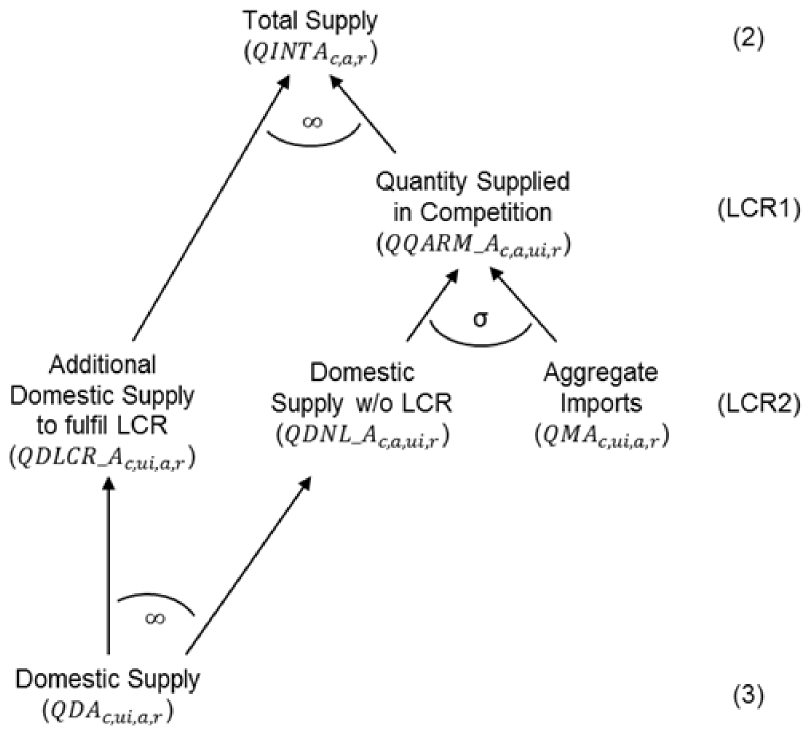
$$QDA_{c,ui,a,r} = QDNL\_A_{c,ui,a,r} - QDLCR\_A_{c,ui,a,r} \quad \text{(INT-M16)}$$

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

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

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

Figure 12. Activity and commodity specific local content requirement



Source: Authors' compilation.

3.3. Price preference instrument

170. The price preference module allows the depiction of 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.[47] A combination with the LCR module is possible.

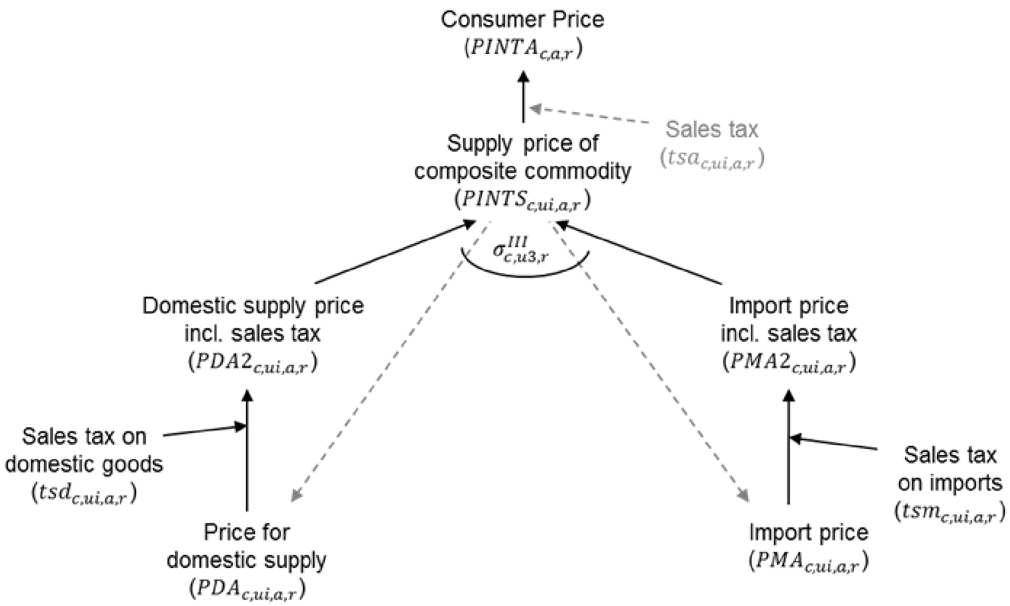
171. In the absence of the module, the sales tax is associated with the composite commodity. For the current policy instrument, the sales tax rate is shifted one level down and constructs sales taxes on domestic commodities and sales taxes on imported commodities. This differentiation deviates from the common practice and the concept of

[47] 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.

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

172. Figure 13 depicts the new point where sales taxes enter into 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.

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

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

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

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

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

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

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

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

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

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

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

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

3.4. Intermediate technology shifter

178. The intermediate technology shifter allows to change the input-output coefficients and thus introduces technical change to the model (e.g. increased use of Information and Communication Technology services (ICTS)). To apply the shifter, the input-output-coefficient is manipulated in the experiment and the change is transmitted to the shift parameter in the first level production function in a co-ordinated manner as described below.

179. For example, a storage requirement increases ICTS costs for all sectors. Each production sector requires more ICTS services per output, which can be interpreted as a technology shift of the input ICTS. First, the use of ICTS in total intermediate inputs is increased in the second level production function for aggregate intermediate input ($QINT_{a,r}$), which intermediate inputs of commodity c in production activity a and region r ($QINTA_{c,a,r}$) are aggregated using Leontief technology:

$$QINTA_{c,a,r} = newioqint_{c,a,r} * QINT_{a,r}$$

ICTS inputs are shocked by the cost increase, $shock_{c,a,r}$, which is obtained from the Business Questionnaire. The values are sector specific, but not region specific. New coefficients ($newioqint_{c,a,r}$) are calculated so that its sum remains equal to 1:

For ICTS inputs:

$$newioqint_{c,a,r} = {QINTA_{c,a,r}^0 * shock_{c,a,r}} \Big/ \left(QINT_{a,r}^0 + QINTA_{c,a,r}^0 * (shock_{c,a,r} - 1)\right)$$

For all other inputs:

$$newioqint_{c,a,r} = ioqint_{c,a,r} * \left(\frac{1 - newioqint_{icts,a,r}}{1 - ioqint_{icts,a,r}} \right)$$

180. Second, the production of good *x* requires more intermediate inputs, which increase by the weighted adjustment of ICTS. It is implemented in the first level CES production function:

$$QX_{a,r} = \alpha * \left[\delta x * QVA_{a,r}^{-\rho x} + (1 - \delta x) * \left(aqint_{a,r} * QINT_{a,r}\right)^{-\rho x} \right]^{-1/\rho x} \quad \text{(Equation P1.5)}$$

and its first order condition:

$$QVA_{a,r} = \left(aqint_{a,r} * QINT_{a,r}\right) * \left(\frac{PINT_{a,r}}{PVA_{a,r}} * \frac{\delta x}{1-\delta x}\right)^{1/1+\rho x} \qquad \text{(Equation P1.6)}$$

Where $aqint_{a,r}$ is the weighted productivity adjuster for the ICTS cost increase:

$$QINTA_{c,a,r} = QINTA^{0}_{c,a,r} * shock_{c,a,r} = newioqint_{c,a,r} * QINT_{a,r}$$

$$aqint_{a,r} = \left(\frac{QINTA^{0}_{icts,a,r} * shock_{icts,a,r}}{newioqint_{icts,a,r} * QINT^{0}_{a,r}}\right)^{-1}$$

Where $QINTA^{0}_{icts,a,r}$ and $QINT^{0}_{a,r}$ are the base levels of activity specific and aggregate intermediate inputs.

The technology shifter can be combined with the LCR module simulating a domestic sourcing requirement.

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Annex A.

Table A.1. Services sector concordance

	GTAP		OECD-ICIO	
Aggregate	Sector Number	ISIC	Sector Number	ISIC
46T48	46	351, 353	D35T39	35,36, 37, 38, 39
	47	352		
	48	36, 37, 38, 39		
49T49	49	41, 42, 43	D41T43	41, 42, 43
50T50	50	45, 46, 47	D45T47	45, 46, 47
51T51	51	55, 56	D55T56	55, 56
52T54	52	49	D49T53	49, 50, 51, 52, 53
	55	52		
	53	50		
	54	51		
56T56	56	53, 58, 59, 60, 61, 62, 63	D58T60	58, 59, 60
			D61	61
			D62T63	62, 63
57T57	57	64, 661, 663	D64T66	64, 65, 66
58T58	58	65, 662	D64T66	64, 65, 66
59T59	59	68	D68	68
60T60	60	M, N	D69T82	69, 70, 71, 72, 73, 74, 75, 77, 78, 79, 80, 81, 82
61T61	61	R, S, T	D90T96	90, 91, 92, 93,94,95, 96
			D97T98	97, 98
62T62	62	84	D84	84
63T63	63	85	D85	85
64T64	64	Q	D86T88	86, 87, 88

Source: Authors' compilation.

Table A.2. Country mapping

	OECD-ICIO	UN Comtrade	GTAP		OECD-ICIO	UN Comtrade	GTAP		OECD-ICIO	UN Comtrade	GTAP		OECD-ICIO	UN Comtrade	GTAP
Albania		alb	alb	Finland	fin	fin	fin	Mongolia		mng	mng	Tunisia	tun	tun	tun
United Arab Em.		are	are	France	fra	fra	fra	Mozambique		moz	moz	Turkey	tur	tur	tur
Argentina	arg	arg	arg	United Kingdom	gbr	gbr	gbr	Mauritius		mus	mus	Taiwan	twn	twn	twn
Armenia		arm	arm	Georgia		geo	geo	Malawi		mwi	mwi	Tanzania		tza	tza
Australia	aus	aus	aus	Ghana		gha	gha	Malaysia	mys	mys	mys	Uganda		uga	uga
Austria	aut	aut	aut	Guinea		gin	gin	Namibia		nam	nam	Ukraine		ukr	ukr
Azerbaijan		aze	aze	Greece	grc	grc	grc	Nigeria		nga	nga	Uruguay		ury	ury
Belgium	bel	bel	bel	Guatemala		gtm	gtm	Nicaragua		nic	nic	US of A	usa	usa	usa
Benin		ben	ben	Hong Kong	hkg	hkg	hkg	Netherlands	nld	nld	nld	Venezuela		ven	ven
Burkina Faso		bfa	bfa	Honduras		hnd	hnd	Norway	nor	nor	nor	Viet Nam	vnm	vnm	vnm
Bangladesh		bgd	bgd	Croatia	hrv	hrv	hrv	Nepal		npl	npl	South Africa	zaf	zaf	zaf
Bulgaria	bgr	bgr	bgr	Hungary	hun	hun	hun	New Zealand	nzl	nzl	nzl	Zambia		zmb	zmb
Bahrain		bhr	bhr	Indonesia	idn	idn	idn	Oman		omn	omn	Zimbabwe		zwe	zwe
Belarus		blr	blr	India	ind	ind	ind	Pakistan		pak	pak	Rest of World*	row		xaa
Bolivia		bol	bol	Ireland	irl	irl	irl	Panama		pan	pan	South Central Africa		xac	xac
Brazil	bra	bra	bra	Iran Islamic Rep. of		irn	irn	Peru	per	per	per	Rest of Cntrl America		xca	xca
Brunei Darussalam	brn	brn	brn	Israel	isr	isr	isr	Philippines	phl	phl	phl	Caribbean		xcb	xcb
Botswana		bwa	bwa	Italy	ita	ita	ita	Poland	pol	pol	pol	Central Africa		xcf	xcf
Canada	can	can	can	Jamaica		jam	jam	Puerto Rico			pri	Rest of East Asia		xea	xea
Switzerland	che	che	che	Jordan		jor	jor	Portugal	prt	prt	prt	Rest of E. Africa		xec	xec
Chile	chl	chl	chl	Japan	jpn	jpn	jpn	Paraguay		pry	pry	Rest of E. Europe		xee	xee
China	chn	chn	chn	Kazakhstan	kaz	kaz	kaz	Qatar		qat	qat	Rest of EFTA		xef	xef
Cote d'Ivoire		civ	civ	Kenya		ken	ken	Romania	rou	rou	rou	Rest of Europe		xer	xer
Cameroon		cmr	cmr	Kyrgyztan		kgz	kgz	Russian Federation	rus	rus	rus	Rest of N. America		xna	xna
Colombia	col	col	col	Cambodia	khm	khm	khm	Rwanda		rwa	rwa	Rest of North Africa		xnf	xnf
Costa Rica	cri	cri	cri	Korea	kor	kor	kor	Saudi Arabia	sau	sau	sau	Rest of Oceania		xoc	xoc
Cyprus	cyp	cyp	cyp	Kuwait		kwt	kwt	Senegal		sen	sen	Rest of South Asia		xsa	xsa
Czech Republic	cze	cze	cze	Lao People's Dem Rep		lao	lao	Singapore	sgp	sgp	sgp	Rest of SA Customs		xsc	xsc
Germany	deu	deu	deu	Sri Lanka		lka	lka	El Salvador		slv	slv	Rest of SE Asia		xse	xse
Denmark	dnk	dnk	dnk	Lithuania	ltu	ltu	ltu	Slovakia	svk	svk	svk	Rest of S. America		xsm	xsm
Dominican Rep.		dom	dom	Luxembourg	lux	lux	lux	Slovenia	svn	svn	svn	Rest of F. Sov Union		xsu	xsu
Ecuador		ecu	ecu	Latvia	lva	lva	lva	Sweden	swe	swe	swe	Rest of the World		xtw	xtw
Egypt		egy	egy	Morocco	mar	mar	mar	Togo		tgo	tgo	Rest of W. Africa		xwf	xwf
Spain	esp	esp	esp	Madagascar		mdg	mdg	Thailand	tha	tha	tha	Rest of Western Asia		xws	xws
Estonia	est	est	est	Mexico	mex	mex	mex	Tajikistan		tjk	tjk				
Ethiopia		eth	eth	Malta	mlt	mlt	mlt	Trinidad and Tobago		tto	tto				