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MIRAGRODEP with Endogenous Tariffs 1.0: Documentation

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Abstract

MIRAGRODEP with endogenous tariffs is a recursive dynamic multi-region, multi-sector Computable General Equilibrium (CGE) model based on MIRAGRODEP which in turn is based on MIRAGE (Modelling International Relations Under Applied General Equilibrium). It constitutes an extension of the MIRAGRODEP model that allows the user to perform analysis involving endogenous tariffs such as designing optimal common external tariffs (CET) in customs unions. The model is particularly suitable for trade policy analysis that require designing optimal levels of tariffs for regional trade agreements.

Résumé

MIRAGRODEP avec tarifs endogènes est un modèle d'équilibre général calculable (EGC) multirégional et multisectoriel dynamique récursif basé sur MIRAGRODEP qui à son tour est basé sur MIRAGE (Modelling International Relations Under Applied General Equilibrium). Il constitue une extension du modèle MIRAGRODEP qui permet à l'utilisateur d'effectuer des analyses impliquant des tarifs endogènes tels que la conception de tarifs extérieurs communs (TEC) optimaux dans les unions douanières. Le modèle est particulièrement adapté à l'analyse des politiques commerciales qui nécessitent la conception de niveaux de tarifs optimaux pour les accords commerciaux régionaux.

1. Introduction

MIRAGRODEP with endogenous tariffs is a Computable General Equilibrium (CGE) model based on MIRAGRODEP which in turn is based on MIRAGE (Modelling International Relations Under Applied General Equilibrium). It is an extension of MIRAGRODEP that allows the user to perform analysis involving endogenous tariffs such as designing optimal common external tariffs (CET) in customs unions. It is a multi-region, multi-sector model, dynamically recursive[1] CGE model. MIRAGE was initially developed at CEPII and devoted to trade policy analysis. As opposed to a single country CGE model, a multi-country CGE model allows a detailed and consistent representation of the Rest of the World. This way, international economic linkages are captured through the international trade of goods and foreign direct investment (FDI).

Social Accounting Matrix (SAM) and trade data in MIRAGRODEP is based on GTAP 10 (Aguiar et al., 2019). The GTAP 10 Data Base is a fully documented, publicly available, global data base which contains complete bilateral trade information, transport and protection linkages among 141 regions for all 65 GTAP commodities for four reference years (2004, 2007, 2011 and 2014). For trade policy data, MAcMAP-HS6 is used.

The objective of this Technical Note is first to describe the mathematical structure[2] of and the economic hypothesis behind the MIRAGRODEP model with endogenous tariffs, version 1.0. In this version of the model, the government is presented separately from the households and thus allows for a better understanding of the impact of shocks on the private and the public sectors distinctly. Since MIRAGRODEP with endogenous tariffs builds upon MIRAGRODEP and MIRAGE and these models have been fully documented, parts of this document are extracts from Decreux and Valin (2007) and Laborde et al. (2013).

The document is organized as follows. In Section 2, we present the main pillars of the model structure, with a summary of equations and variables mapped to their counterparts in GAMS code. In the third section we show how to run the model.

2. Model Structure

2.1 Dimensions and sets

The MIRAGRODEP model includes many sets, and we present here the main ones. Other specific sets attached to modules will be introduced as we present these modules.

[1] Dynamically recursive models do not include expectation of value of variables in future periods in the model. The value of variable X at the end of period t is the initial value of variable X at the beginning of period t+1.

[2] For a comprehensive review of the functional forms commonly used in CGE models, please refer to Femenia (2012).

The core model distinguishes multiple sectors (or activities, industries) each of them producing one single commodity (or good, product). Sectors and commodities are referred to using indices *i* or *j*, both representing the exact same elements. The subset *Transport* refers to the transportation commodities and sectors.

MIRAGRODEP is a global dynamic model. Each variable is thus indexed in time (index t) and by region using indices r (origin country), s (destination country), *rr* and *ss*, which all correspond to the same elements.

Set *f* refers to the five (5) factors of production: skilled labor (index *SkLab*), unskilled labor (*UnSkLab*), natural resources (*NatlRes*), capital (*Capital*) and land (*Land*). As will be discussed below, it is assumed that unskilled workers are not perfectly mobile across sectors of production. Hence, sectors are grouped according to the area, (rural (*L1*) or urban (*L2*), both elements being included in set *Ltype*. Gender consists of male and female dimensions.

2.2 Production

The production in each sector and in each region follows the nested structure depicted in Figure 1 below. At the top level, total output $Y_{j,r,t}$ is a Leontief of total value added, $VA_{j,r,t}$, and of total intermediate consumption, $CNTER_{j,r,t}$. In other words, there are no substitution possibilities between the two aggregated inputs, they are used in perfect complementarity, and thus their shares in total production are constant.

Mathematically:

$$Y_{j,r,t} = a_{j,r}^{VA} * \left(1 - IceTr_{j,r,t}\right) * MFPI_{j,r,t} * VA_{j,r,t} \quad (1)$$

$$Y_{j,r,t} = a_{j,r}^{CNTER} * \left(1 - IceTr_{j,r,t}\right) * MFPI_{j,r,t} * \ CNTER_{j,r,t} \quad (2)$$

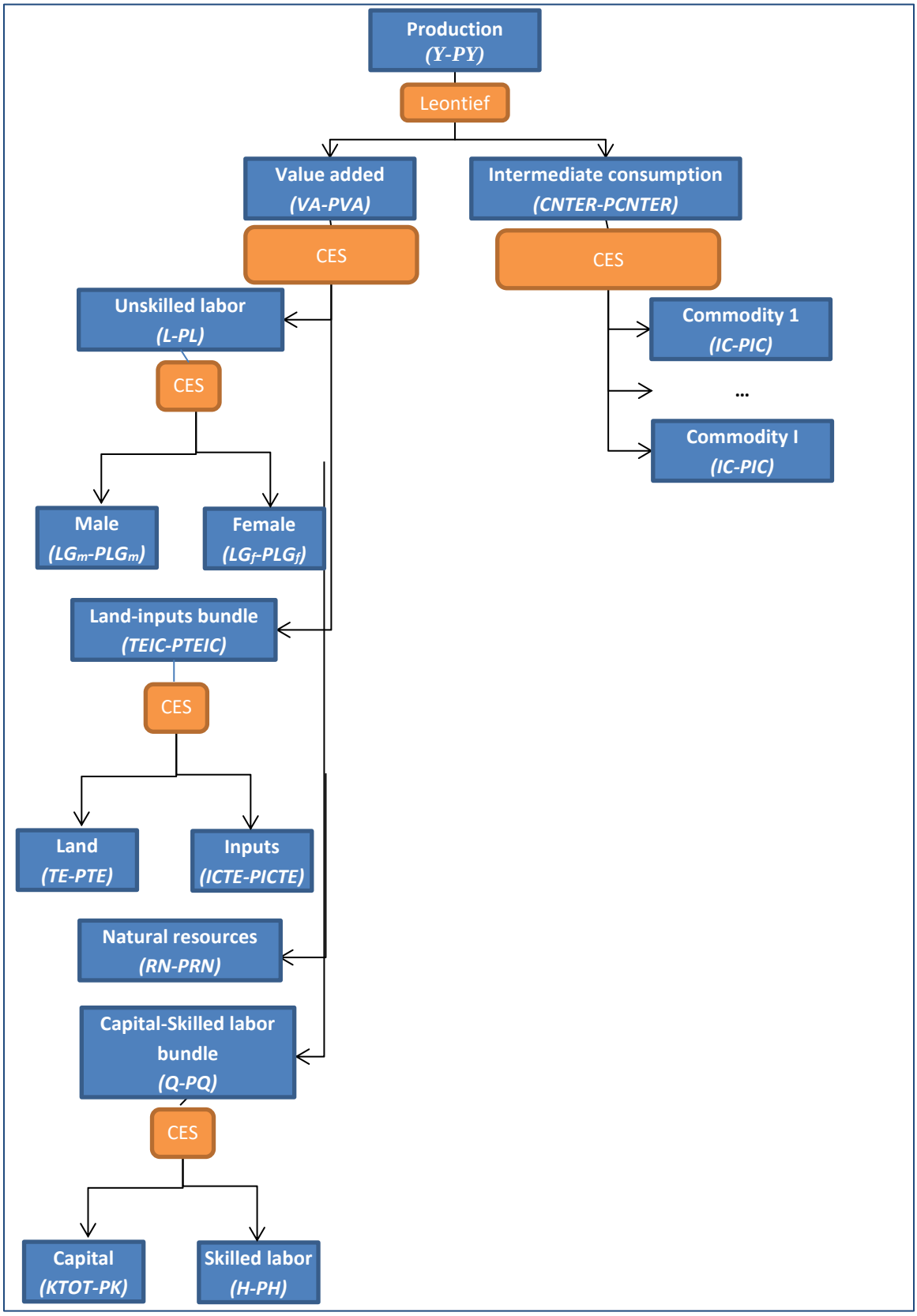
with

$a_{j,r}^{VA}$	Value added scale coefficient
$a_{j,r}^{CNTER}$	Total intermediate consumption scale coefficient
$IceTr_{j,r,t}$	Iceberg cost for transportation time shadow price
$MFPI_{j,r,t}$	Multifactor productivity parameter

Hence, the producer price of output, $PY_{j,r,t}$, is a weighted sum of the price of value added, $PVA_{j,r,t}$, and of that of total intermediate consumption, $PCNTER_{j,r,t}$.

$$PY_{j,r,t}\ Y_{j,r,t} = PVA_{j,r,t}\ VA_{j,r,t} + PCNTER_{j,r,t}\ CNTER_{j,r,t} \quad (3)$$

Figure 1. Nested production function[3]



At the second level, on the value added side, total value added is a combination of unskilled labor, $L_{j,r,t}$, a land and substitutable inputs bundle, $TEIC_{j,r,t}$, natural resources, $RN_{j,r,t}$, and capital-skilled labor bundle, $Q_{j,r,t}$. Unskilled labor is a CES aggregate of labor of different genders $LG_{gender,j,r,t}$. The representative firm minimizes its costs subject to the CES aggregator, which yields the following first order conditions:

$$L_{j,r,t} = a_{j,r}^{L}\, VA_{j,r,t}\, PGFI_{j,r,t}^{\sigma_j^{VA}-1} \left(\frac{PVA_{j,r,t}}{PL_{j,r,t}}\right)^{\sigma_j^{VA}} \quad (4)$$

$$LG_{gender,j,r,t} = a_{gender,j,r}^{LG} L_{j,r,t} \left(\frac{PL_{j,r,t}}{PLG_{gender,j,r,t}}\right)^{\sigma_{unsklab,j,r}^{gender}} \quad (5)$$

$$PL_{j,r,t} * L_{j,r,t} = \sum_{gender} LG_{gender,r,j,t} * PLG_{gender,r,j,t} \quad (6)$$

$$TEIC_{j,r,t} = a_{j,r}^{TEIC} \cdot VA_{j,r,t} \cdot \left(\frac{PVA_{j,r,t}}{PTEIC_{j,r,t}}\right)^{\sigma_j^{VA}} \quad (7)$$

$$ICTE_{j,r,t} = a_{j,r}^{ICTE} \cdot TEIC_{j,r,t} \cdot \left(\frac{PTEIC_{j,r,t}}{PICTE_{j,r,t}}\right)^{\sigma_{j,r}^{TEIC}} \quad (8)$$

$$TE_{j,r,t} = a_{j,r}^{TE} * TEIC_{j,r,t} * \left[\left(PGFI_{j,r,t} - 1\right) * TE_{j,r,t}^{productivity} + 1\right]^{\sigma_{j,r}^{TEIC}-1} \cdot \left(\frac{PTEIC_{j,r,t}}{PTE_{j,r,t}}\right)^{\sigma_{j,r}^{TEIC}} \quad (9)$$

$$RN_{j,r,t} = a_{j,r}^{RN} \cdot VA_{j,r,t} \cdot PGFI_{r,t}^{\sigma_j^{VA}-1} \left(\frac{PVA_{j,r,t}}{PRN_{j,r,t}}\right)^{\sigma_j^{VA}} \quad (10)$$

$$Q_{j,r,t} = a_{j,r}^{Q} \cdot VA_{j,r,t} \cdot PGFI_{r,t}^{\sigma_j^{VA}-1} \cdot \left(\frac{PVA_{j,r,t}}{PQ_{j,r,t}}\right)^{\sigma_j^{VA}} \quad (11)$$

with

$a_{j,r}^{L}$	Unskilled labor coefficient
$a_{j,r}^{TE\mathrm{IC}}$	Land-inputs bundle coefficient
$a_{j,r}^{\mathrm{IC}TE}$	Substituable inputs coefficient
$a_{j,r}^{\mathrm{TE}}$	Land coefficient
$a_{j,r}^{RN}$	Natural resources coefficient
$a_{j,r}^{Q}$	Capital-skilled labor aggregate coefficient
σ_j^{VA}	Value added elasticity
$\sigma_{j,r}^{\mathrm{TEIC}}$	Elasticity of substitution between land and key inputs

$\sigma^{\text{gender}}_{\text{unsklab},j,\text{r}}$	Elasticity of substitution between various gender group
$PGFI_{r,t}$	Total factor productivity - sectoral shifter
$\text{TE}^{\text{productivity}}_{\text{j,r,t}}$	Land Productivity factor

It follows that the price of value added is a weighted sum of the price of unskilled labor, $PL_{j,r,t}$ the price of land-inputs bundle, $PTEIC_{j,r,t}$ the price of natural resources, $PRN_{j,r,t}$, and the aggregated price of capital and skilled workers, $PQ_{j,r,t}$.

$$PVA_{j,r,t}\, VA_{j,r,t} = PL_{j,r,t}\, L_{j,r,t} + PTEIC_{j,r,t}\, TEIC_{j,r,t} + PRN_{j,r,t}\, RN_{j,r,t} + PQ_{j,r,t}\, Q_{j,r,t} \qquad (12)$$

The price of the bundle $PTEIC_{j,r,t}$ is a weighted sum of the price of land $PTE_{j,r,t}$ and the price of the inputs $PICTE_{j,r,t}$.

$$PTEIC_{j,r,t} TEIC_{j,r,t} = PTE_{j,r,t} TE_{j,r,t} + PICTE_{j,r,t} ICTE_{j,r,t} \qquad (13)$$

The price paid by the producer for each factor differs from the one received by the households by the amount of taxes, which can be negative in the cases where factors are subsidized. The model also distinguishes ad valorem taxes from taxes that are applied on volume. Hence:

$$PLG_{gender,j,r,t} = [\textstyle\sum_{Ltype} WLGt_{Ltypegender,r,t}] \left(1 + taxf^{VAL}_{UnSkLab,j,r,t}\right) + PIndC_{r,t}\, taxf^{VOL}_{UnSkLab,j,r,t} \qquad (14)$$

$$PTE_{j,r,t} = WTE_{j,r,t} \left(1 + taxf^{VAL}_{Land,j,r,t}\right) + PIndC_{r,t}\, taxf^{VOL}_{Land,j,r,t} \qquad (15)$$

$$PRN_{j,r,t} = WRN_{j,r,t} \left(1 + taxf^{VAL}_{NatlRes,j,r,t}\right) + PIndC_{r,t}\, taxf^{VOL}_{NatlRes,j,r,t} \qquad (16)$$

with

$WLGt_{Ltypegender,r,t}$	Rate of return to unskilled labor (net of taxes)
$WTE_{j,r,t}$	Rate of return to land (net of taxes)
$PTE_{j,r,t}$	Price of land (including taxes)
$WRN_{j,r,t}$	Rate of natural resources (net of taxes)
$PIndC_{r,t}$	Consumer price index
$taxf^{VAL}_{f,j,r,t}$	Rate of factor-based taxes (ad valorem)
$taxf^{VOL}_{f,j,r,t}$	Rate of factor-based taxes (on volume)

At the bottom level, on the value added side, capital, $KTOT_{j,r,t}$ and skilled labor, $H_{j,r,t}$, are combined through a CES function, once again to represent the imperfect substitutability between the two factors of production. Minimization of production costs subject to the CES aggregator gives the following demand functions:

$$H_{j,r,t} = a_{j,r}^{H}\, Q_{j,r,t} \left(\frac{PQ_{j,r,t}}{PH_{j,r,t}}\right)^{\sigma_j^{CAP}} \quad (17)$$

$$HG_{gender,j,r,t} = a_{gender,j,r}^{HG} H_{j,r,t} \left(\frac{PH_{j,r,t}}{PHG_{gender,j,r,t}}\right)^{\sigma_{sklab,j,r}^{gender}} \quad (18)$$

$$PH_{j,r,t} H_{j,r,t} = \sum_{gender} PHG_{gender,j,r,t} HG_{gender,j,r,t} \quad (19)$$

$$KTOT_{j,r,t} = a_{j,r}^{K}\, Q_{j,r,t} \left(\frac{PQ_{j,r,t}}{PK_{j,r,t}}\right)^{\sigma_j^{CAP}} \quad (20)$$

with

$a_{j,r}^{H}$	aggregate skilled labor coefficient
$a_{gender,j,r}^{HG}$	skilled labor coefficient
$a_{j,r}^{K}$	Capital coefficient
σ_j^{CAP}	Capital-skilled labor elasticity
$\sigma_{sklab,j,r}^{gender}$	Elasticity of substitution skilled labor

The price of the capital-skilled labor bundle is thus a weighted sum of the rental rate of capital, $PK_{j,r,t}$, and of the price of skilled labor, $PH_{j,r,t}$.

$$PQ_{j,r,t}\, Q_{j,r,t} = PK_{j,r,t}\, KTOT_{j,r,t} + PH_{j,r,t}\, H_{j,r,t} \quad (21)$$

Again, the prices paid for the factors of production differ from the ones received by households as there are taxes levied on each of them.

$$PHG_{gender,j,r,t} = WHG_{gender,r,t} \left(1 + taxf_{SkLab,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{SkLab,j,r,t}^{VOL} \quad (22)$$

$$PK_{j,r,t} = WK_{j,r,t} \left(1 + taxf_{Capital,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{Capital,j,r,t}^{VOL} \quad (23)$$

with

$WHG_{gender,r,t}$	Rate of return to skilled labor (net of taxes)
$WK_{j,r,t}$	Rate of return to capital (net of taxes)

On the intermediate consumption side, the commodities (index *i*) used in the production process are assumed to be imperfect substitutes. Once again, a CES function is used to represent this imperfect substitutability, and cost minimization yields the demand for each input, $IC_{i,j,r,t}$:

$$IC_{i,j,r,t} = \left[a_{i,j,r}^{IC}\left(1 + TrTCost_{i,j,r,t}\right)^{\sigma_j^{IC}-1} CNTER_{j,r,t} \left(\frac{PCNTER_{j,r,t}}{PIC_{i,j,r,t}}\right)^{\sigma_j^{IC}}\right] \$not\ map_{i,j,r}^{TEIC} +$$

$$\left[a_{i,j,r}^{IC}\left(1 + TrTCost_{i,j,r,t}\right)^{\sigma_j^{ICTE}-1} ICTE_{j,r,t} \left(\frac{PICTE_{j,r,t}}{PIC_{i,j,r,t}}\right)^{\sigma_j^{ICTE}}\right] \$map_{i,j,r}^{TEIC} \quad (24)$$

with

$a_{i,j,r}^{IC}$	Intermediate consumption scale coefficient
σ^{IC}	Intermediate consumption elasticity
σ_j^{ICTE}	elasticity of substitution across inputs used for substitution with lands
$map_{i,j,r}^{TEIC}$	Mapping set for land input substitutions

The price of total intermediate consumption is a weighted sum of the price paid for each commodity, $PIC_{i,j,r,t}$.

$$PCNTER_{j,r,t}\ CNTER_{j,r,t} = \sum_{i\$not\ map_{i,j,r}^{TEIC}} PIC_{i,j,r,t}\ IC_{i,j,r,t} \quad (25)$$

$$PICTE_{j,r,t}\ ICTE_{j,r,t} = \sum_{i\$map_{i,j,r}^{TEIC}} PIC_{i,j,r,t}\ IC_{i,j,r,t} \quad (26)$$

The price of each input is subject to taxes, $taxicc_{i,j,r,t}$, and thus differ from the price received by producers $PDEMTOT_{i,r,t}$.

$$PIC_{i,j,r,t} = PDEMTOT_{i,r,t}\left(1 + taxicc_{i,j,r,t}\right) \quad (27)$$

2.3 Income and savings

2.3.1 Households

Households are assumed to be homogenous and they own all factors of production. They, hence, receive all the payments made to factors of production. They also receive transfers from the government, which are indexed to take into account population growth and the evolution of the price index.

$$REVH_{r,t} = \sum_j\left\{WRN_{j,r,t}\ RN_{j,r,t} + WTE_{j,r,t} \cdot TE_{j,r,t} + \sum_s WK_{j,s,t}\ K_{j,r,s,t}\right\} +$$

$$Shiftpop_{poptotal,r,t} Population_{poptotal,r,t} TRH_{r,t}\ PIndC_{r,t} -$$

$$Shiftpop_{poptotal,r,t} Population_{poptotal,r,t} lumpsum_{r,t} + \left(1 -$$

$$TaxEfficiency_{r,t}\right)\left\{\left[\sum_i RECPROD_{i,r,t} + RECFAC_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} +\right.\right.$$

$$RECCONS_{i,r,t}\big] + RECDIR_{r,t}\big\} + \big(1 - TariffEfficiency_{r,t}\big)\big[\sum_{s,i} PCIF_{i,s,r,t} DD_{i,s,r,t} TRADE_{i,s,r,t}\big] + \sum_{gender} WHG_{gender,r,t}\bar{H}_{gender,r,t} + WLG_{gender,r,t}\bar{L}_{gender,r,t} \quad (28)$$

with

$REVH_{r,t}$	Households' income
$TRH_{r,t}$	Public transfers to households
$\text{Shiftpop}_{\text{poptotal,r,t}}$	Population shifter
$\text{TaxEfficiency}_{\text{r,t}}$	Tax efficiency parameter
$\text{TariffEfficiency}_{\text{r,t}}$	Tariff efficiency parameter

Households savings, $SAVH_{r,t}$, are a fixed proportion epa_r of their income net of direct taxes, $RECDIR_{r,t}$ and of the remittances $REM_{r,s,t}$, and the rest of their income is dedicated to consumption budget, $BUDH_{r,t}$.

$$SAVH_{r,t} = epa_r\ (REVH_{r,t} - RECDIR_{r,t} - \sum_s REM_{r,s,t} + \sum_s REM_{s,r,t}) \quad (29)$$

$$BUDH_{r,t} = REVH_{r,t} - SAVH_{r,t} - RECDIR_{r,t} - \sum_s REM_{r,s,t} + \sum_s REM_{s,r,t} \quad (30)$$

2.3.2 Government

The income of the government, $REVG_{r,t}$, consists of taxes collected on production, $RECPROD_{i,r,t}$, on factors of production, $RECFAC_{i,r,t}$, on exports, $RECEXP_{i,r,t}$, on imports, $RECDD_{i,r,t}$,on consumption, $RECCONS_{i,r,t}$, and households' income, $RECDIR_{r,t}$.

$$REVG_{r,t} = TaxEfficiency_{r,t} * \sum_i \big\{RECPROD_{i,r,t} + RECFAC_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t}\big\} + RECDIR_{r,t} + Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} * lumpsum_{r,t} \quad (31)$$

With

$lumpsum_{r,t}$	Lumpsum tax

Taxes on production are collected on the value of output of each activity. It is important to note that tax rates should be considered as *net* rates, that is taxes net of subsidy. Hence, all tax rates can be either positive or negative.

$$RECPROD_{i,r,t} = taxP_{i,r,t}\ PY_{i,r,t}\ Y_{i,r,t} \quad (32)$$

with

$taxP_{i,r,t}$	Production tax rate

Receipt from taxes on factors of production is the sum of volume and value taxes on each factor.

$$RECFAC_{j,r,t} = PIndC_{r,t}\,[taxf^{VOL}_{Land,j,r,t}\,TE_{j,r,t} + \left(\sum_{gender} taxf^{VOL}_{Sklab,j,r,t} HG_{gender,j,rt} + taxf^{VOL}_{UnSklab,j,r,t} LG_{gender,j,rt}\right) + taxf^{VOL}_{NatlRes,j,r,t}\,RN_{j,r,t} + taxf^{VOL}_{Capital,j,r,t}\,KTOT_{j,r,t}] + taxf^{VAL}_{Land,j,r,t}\,WTE_{j,r,t}\,TE_{j,r,z,t} + \sum_{gender} taxf^{VAL}_{Sklab,j,r,t} WHG_{gender,j,r,t} HG_{gender,j,rt} + taxf^{VAL}_{UnSklab,j,r,t} * \sum_{Ltype} WLGt_{Ltype,gender,r,t} LG_{gender,j,r,t} + taxf^{VAL}_{NatlRes,j,r,t}\,WRN_{j,r,t}\,RN_{j,r,t} + taxf^{VAL}_{Capital,j,r,t}\,WK_{j,r,t}\,KTOT_{j,r,t} \qquad (33)$$

Exports may be subject to three taxes: taxes on production, $taxP_{i,r,t}$, regular taxes on exports, $taxEXP_{i,r,s,t}$, and export tax equivalent of multi-fiber arrangement quota premium, $taxAMF_{i,r,s,t}$.

$$RECEXP_{i,r,t} = PY_{i,r,t}\left(1 + taxP_{i,r,t}\right)\sum_s \left(taxEXP_{i,r,s,t} + taxAMF_{i,r,s,t}\right) TRADE_{i,r,s,t} \qquad (34)$$

with

$TRADE_{i,r,s,t}$ Exports of commodity *i* from country *r* to country *s*

Duties, $DD_{i,s,r,t}$, are collected on imports evaluated at the CIF price, $PCIF_{i,s,r,t}$.

$$RECDD_{i,r,t} = TariffEfficiency_{r,t} * \sum_s DD_{i,s,r,t}\,PCIF_{i,s,r,t}\,TRADE_{i,s,r,t} \qquad (35)$$

Taxes are levied on households' consumption, $CH_{i,r,t}$, government current expenditure on goods and services, $CG_{i,r,t}$, on commodities sold for investment purposes, $KG_{i,r,t}$, and on intermediate consumption, $IC_{i,j,r,t}$. Each buyer faces a specific tax rate, respectively , $taxcc_{i,r,t}$, $taxgc_{i,r,t}$, $taxkgc_{i,r,t}$, and $taxicc_{i,j,r,t}$ plus the additional $addtaxcc_{r,t}$ if the public closure option is 2 or 5.

$$RECCONS_{i,r,t} = PDEMTOT_{i,r,t}\left\{(taxcc_{i,r,t} + addtaxcc_{r,t})\,CH_{i,r,t} + (taxgc_{i,r,t} + addtaxcc_{r,t})CG_{i,r,t} + (taxkgc_{i,r,t} + addtaxcc_{r,t})\,KG_{i,r,t} + \sum_j taxicc_{i,j,r,t}\;IC_{i,j,r,t}\right\} \qquad (36)$$

With

$addtaxcc_{r,t}$ additional consumption tax for specific public closures

Finally, the government collects direct taxes on households' income:

$$RECDIR_{r,t} = [taxdir_{r,t} + addtaxdir_{r,t}]\,REVH_{r,t} \qquad (37)$$

With

$addtaxdir_{r,t}$ additional income tax for specific public closures

Government savings, $SAVG_{r,t}$, are assumed to be a fixed proportion, $PUBSOLD_r$, of GDP at market prices, $GDPMP_{r,t}$.

$$SAVG_{r,t} = PUBSOLD_r \; GDPMP_{r,t} \quad (38)$$

The budget allocated to public current expenditure on goods and services, BUDGr,t, is determined by:

$$BUDG_{r,t} = \sum_i PCG_{i,r,t} CG_{i,r,t} + Realbudget\_pc_r \prod_i PC_{i,r,t}{}^{\alpha\_g_{i,r}} * Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} \quad (39)$$

Finally the compensation tax (either lumpsum or consumption tax or income tax) to maintain public budget constant in percentage of GDP is given by:

$$BUDG_{r,t} = REVG_{r,t} - SAVG_{r,t} - Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} * TRH_{r,t} * PIndC_{r,t} \quad (40)$$

2.4 Demand

Domestic absorption of each commodity, $DEMTOT_{i,r,t}$, is the sum of consumer demand, $CH_{i,r,t}$ demand from public administrations, $CG_{i,r,t}$ intermediate demand, $IC_{i,j,r,t}$ and demand for investment purposes, $KG_{i,r,t}$.

$$DEMTOT_{i,r,t} = CH_{i,r,t} + CG_{i,r,t} + \sum_j IC_{i,j,r,t} + KG_{i,r,t} \quad (41)$$

2.4.1 Private demand

Households' demand is characterized by a LES-CES (Linear Expenditure System - Constant Elasticity of Substitution) specification across aggregate goods, the latter being a CES function of sub-groups. This specific utility function allows the evolution of the demand structure of each region to be accounted for as its income level changes. Additionally, the elasticity of substitution is constant only among the sectoral consumptions over and above a minimum level. The minimal level of consumption can vary across region (e.g. developing versus developed country).

$$CHC_{AGI,r,t} = Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} \left(cmin_{AGI,r,t} + a^{CC}_{AGI,r} \; AUX_{r,t} \left(\frac{P_{r,t}}{PCC_{AGI,r,t}} \right)^{\sigma^{CC}_{r,t}} \right) \quad (42)$$

$$CH_{i,r,t} = a^{C}_{i,r,t} * \sum_{AGI\$mapAGI(i,AGI)} CHC_{AGI,r,t} * \left[\frac{\sum_{AGI\$mapAGI(i,AGI)} PCC_{AGI,r,t}}{PC_{i,r,t}} \right]^{\sum_{AGI\$mapAGI(i,AGI)} \sigma^{C}_{r,AGI,t}} \quad (43)$$

with

$cmin_{\mathrm{AGI},r,t}$ Minimal consumption of aggregate commodity AGI (per capita)

$a^{CC}_{\mathrm{AGI},r}$	Household consumption coefficient
$AUX_{r,t}$	Utility
$P_{r,t}$	Shadow price of utility
$PC_{i,r,t}$	Price of final private consumption
$PCC_{\mathrm{AGI},r,t}$	Price of final private consumption for composite sectors
σ^{CC}_{r}	Households composite goods consumption elasticity of substitution
$\sigma^{C}_{r,\mathrm{AGI,t}}$	Households consumption elasticity of substitution

Households maximize their utility subject to their consumption budget, $BUDH_{r,t}$, from which one can derive the shadow price of utility, $P_{r,t}$.

$$BUDH_{r,t} = \sum_i PC_{i,r,t}\, CH_{i,r,t} \qquad (44)$$

$$P_{r,t}\, AUX_{r,t} = \sum_{AGI} PCC_{AGI,r,t} \left(\frac{CHC_{AGI,r,t}}{Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t}} - cmin_{AGI,r,t} \right) \qquad (45)$$

The price paid by household for each commodity, $PC_{i,r,t}$, differs from the one received by the suppliers, $PDEMTOT_{i,r,t}$, by the amount of taxes collected, $taxcc_{i,r,t}$ and the additional tax $addtaxcc_{r,t}$ if the public closure option is 2 or 5.

$$PC_{i,r,t} = PDEMTOT_{i,r,t} \left(1 + taxcc_{i,r,t} + addtaxcc_{r,t}\right) \qquad (46)$$

The price of final private consumption for composite sectors is given by:

$$PCC_{AGI,r,t} * CHC_{AGI,r,t} = \sum_{i\$mapAGI(i,AGI)} PC_i * CH_i \qquad (47)$$

Finally, the consumer price index, $PIndC_{r,t}$, is a Fisher index.

$$PindC_{r,t} = \sqrt{\left[\frac{\sum_i PC_{i,r,t}\, CH^{O}_{i,r}}{\sum_i PC^{O}_{i,r}\, CH^{O}_{i,r}}\right] \left[\frac{\sum_i PC_{i,r,t}\, CH_{i,r,t}}{\sum_i PC^{O}_{i,r}\, CH_{i,r,t}}\right]} \qquad (48)$$

with

$CH^{O}_{i,r}$	Benchmark value of households' consumption
$PC^{O}_{i,r}$	Benchmark value of final private consumption

2.4.2 Public demand

Government spending on each commodity is a fixed share, $\alpha^{G}_{i,r}$, of total public expenditure in goods and services, $BUDG_{r,t}$, and government purchases are subject to taxes, $taxgc_{i,r,}$ and $addtaxcc_{r,t}$ if the public closure option is 2 or 5.

$$CG_{i,r,t} = \alpha^{G}_{i,r}\ \frac{BUDG_{r,t}}{PCG_{i,r,t}}\$(pubclosure = \{0, or\ 4\ or\ 5) + \frac{CG0_{i,r} * Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t}}{* Shiftpop_{poptotal,r,t0,ref} * Population_{poptotal,r,t0}}\$(pubclosure \neq \{0,4,5\} \quad (49)$$

$$PCG_{i,r,t} = PDEMTOT_{i,r,t}\left(1 + taxgc_{i,r,t} + addtaxcc_{r,t}\right) \quad (50)$$

with

$PCG_{i,r,t}$ Price of final public consumption

2.4.3 Demand for investment purposes

Finally, demand for investment purposes, $KG_{i,r,t}$, is characterized by a CES function. Cost minimization subject to the CES aggregator yields the following demand function:

$$KG_{i,r,t} = a^{KG}_{i,r}\ INVTOT_{r,t}\left(\frac{PINVTOT_{r,t}}{PKG_{i,r,t}}\right)^{\sigma^{KG}} \quad (51)$$

with

$a^{KG}_{i,r}$ Capital good scale coefficient

$INVTOT_{r,t}$ Total investment

$PINVTOT_{r,t}$ Price of investment

$PKG_{i,r,t}$ Price of capital good consumption

σ^{KG} Capital good elasticity

The aggregated price of capital, $PINVTOT_{r,t}$, is thus a weighted sum of the price paid for each commodity, $PKG_{i,r,t}$.

$$PINVTOT_{r,t}\ INVTOT_{r,t} = \sum_i PKG_{i,r,t}\ KG_{i,r,t} \quad (52)$$

Again, the price paid by the purchaser differs from the one received by the seller, as taxes apply, including the additional one when the public closure option is 2 or 5.

$$PKG_{i,r,t} = PDEMTOT_{i,r,t}\left(1 + taxkgc_{i,r,t} + addtaxcc_{r,t}\right) \quad (53)$$

2.4.4 Demand by geographic origin

MIRAGRODEP is a bilateral trade model consistent with the Armington assumption: commodities are assumed to be heterogeneous according to their origin, and thus, imperfect substitutes for one another (Armington 1969). Nested CES functions are used to reflect preferences among varieties originating from different countries. Therefore, countries can export and import the same product at the same time due to consumer preferences for different varieties. The price transmission between domestic and international market is imperfect and highly dependent on the choice of the CES trade elasticities and the initial share of trade.

At the top level, total demand, $DEMTOT_{i,r,t}$, combines aggregated imports, $M_{i,r,t}$, and local production, $D_{i,r,t}$, through a CES function. From cost minimization subject to the CES aggregator, the following demand functions can be derived:

$$D_{i,r,t} = a_{i,r}^{D}\, DEMTOT_{i,r,t} \left(\frac{PDEMTOT_{i,r,t}}{PD_{i,r,t}}\right)^{\sigma_i^{ARM}} \quad (54)$$

$$M_{i,r,t} = a_{i,r}^{M}\, DEMTOT_{i,r,t} \left(\frac{PDEMTOT_{i,r,t}}{PM_{i,r,t}}\right)^{\sigma_i^{ARM}} \quad (55)$$

with

$a_{i,r}^{D}$	Local demand scale coefficient
$a_{i,r}^{M}$	Total import demand scale coefficient
σ_i^{ARM}	Armington elasticity
$PD_{i,r,t}$	Price of demand for domestic commodity
$PM_{i,r,t}$	Aggregated price of imports

Consequently, the price of the aggregated commodity, $PDEMTOT_{i,r,t}$, is a weighted sum of aggregated imports, $PM_{i,r,t}$, and of the price of the domestically produced commodity, $PD_{i,r,t}$, which differs from the amount received by the producer, $PY_{i,r,t}$, since taxes, $taxP_{i,r,t}$, apply.

$$PDEMTOT_{i,r,t}\, DEMTOT_{i,r,t} = PD_{i,r,t}\, D_{i,r,t} + PM_{i,r,t}\, M_{i,r,t} \quad (56)$$

$$PD_{i,r,t} = PY_{i,r,t}\, (1 + taxP_{i,r,t}) \quad (57)$$

At the second level, a two level Armington tree determines imports. Total imports, $M_{i,r,t}$, are a CES combination of imports from a group of different trading partners, $ARM_{i,Arm1,r,t}$, the latter being a CES

combination of imports from different countries, $DEMA_{i,s,r,t}$. Cost minimization under the CES aggregation constraint leads to the following demand functions:

$$ARM_{i,Arm1,r,t} = a_{i,Arm1,r}^{ARM} \, M_{i,r,t} \left(\frac{PM_{i,r,t}}{PARM_{i,Arm1,r,t}} \right)^{\sigma_{i,r}^{Arm1}} \quad (58)$$

$$ARM_{i,Arm1,r,t} * PARM_{i,Arm1,r,t} = \sum_{s\$Armtree(i,r,s,Arm1)} PDEMA_{i,s,r,t} * DEMA_{i,s,r,t} \quad (59)$$

$$DEMA_{i,s,r,t} = a_{i,s,r}^{IMP} * \sum_{Arm1} ARM_{i,Arm1,r,t} \left(\frac{\sum_{Arm1} PARM_{i,Arm1,r,t}}{PDEMA_{i,s,r,t}} \right)^{\sigma_{i,Arm1,r}^{IMP}} \quad (60)$$

With

$a_{i,\mathrm{Arm1},r}^{\mathrm{ARM}}$	First leve of Armington tree scale coefficient
$\sigma_{i,\mathrm{r}}^{\mathrm{Arm1}}$	Armington elasticity 1 (CES Domestic and Imports)
$\sigma_{i,\mathrm{Arm1,r}}^{IMP}$	Import elasticity (CES - Total imports)
$P\mathrm{ARM}_{i,\mathrm{Arm1},r,t}$	Price of Armington aggregate first level
$PDEMA_{i,s,r,t}$	Price of bilateral trade

This specification implies that the price of aggregated imports is a weighted sum of the price paid to the different partners. The price paid by the purchaser differs from the CIF price as import duties, $DD_{i,s,r,t}^{A}$, apply.

$$PM_{i,r,t} \, M_{i,r,t} = \sum_{Arm1} ARM_{i,Arm1,r,t} * PARM_{i,Arm1,r,t} \quad (61)$$

$$PDEMA_{i,s,r,t} = PCIF_{i,s,r,t} \left(1 + DD_{i,s,r,t}^{A}\right) \quad (62)$$

And the CIF price is determined by the production costs, on which taxes apply, plus the transportation costs.

$$PCIF_{i,s,r,t} = PY_{i,s,t} \left(1 + taxEXP_{i,s,r,t} + taxAMF_{i,s,r,t}\right) \left(1 + taxP_{i,s,t}\right) + MUO_{i,s,r} \, PTr_{i,s,r,t} \quad (63)$$

with

$Ptr_{i,s,r,t}$	Price of transportation per commodity exported
$MUO_{i,s,r}$	Transport coefficient

Following the consistent aggregator methodology as defined in (Laborde, Martin, and van der Mensbrugghe, 2011), aggregation of volumes differ whether they are estimated at world prices or at domestic prices. Hence, the shadow price of bilateral trade, $PDEM_{i,s,r,t}$, is evaluated as follow:

$$PDEM_{i,s,r,t} = PCIF_{i,s,r,t}\left(1 + DD_{i,s,r,t}\right) \quad (64)$$

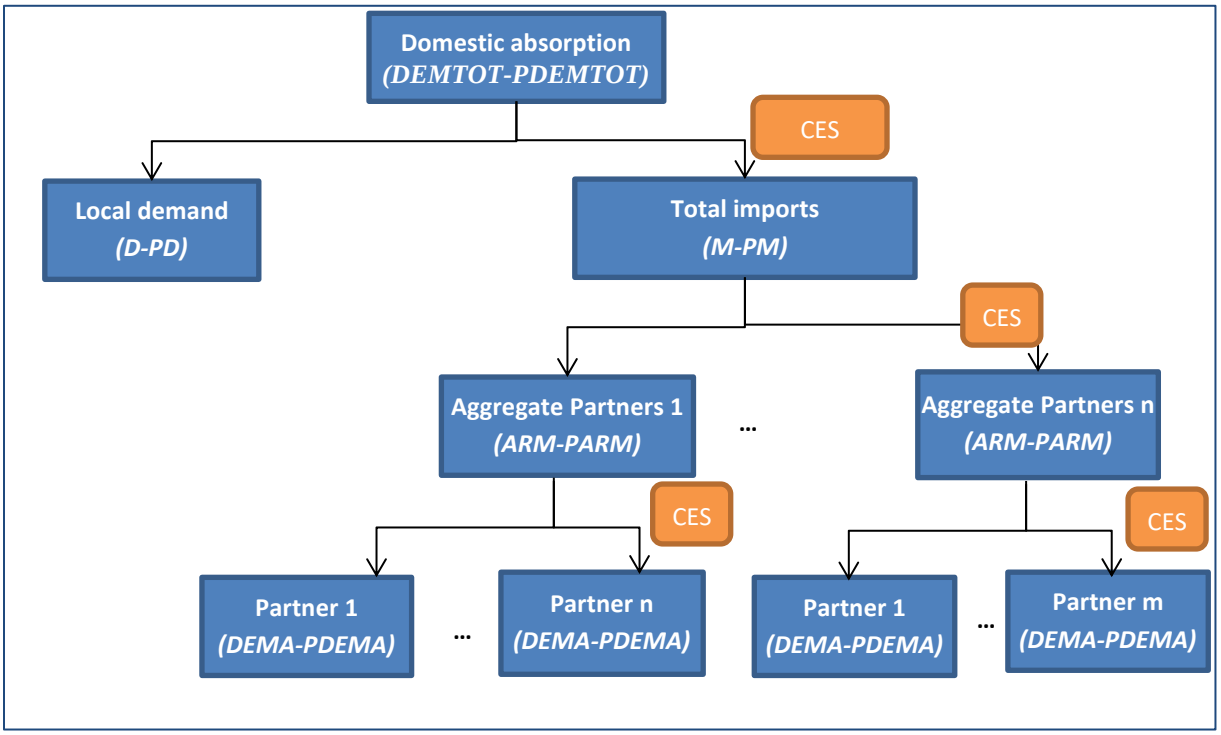
which leads to the definition of the aggregator $TRADE_{i,s,r,t}$:

$$DEMA_{i,s,r,t}\, PDEMA_{i,s,r,t} = PDEM_{i,s,r,t}\, TRADE_{i,s,r,t} \quad (65)$$

And $DD^{A}_{i,s,r,t}$ and $DD_{i,s,r,t}$ are matched via:

$$DD^{A}_{i,s,r,t} = DD^{A}_{i,s,r,t,ref}.L + [DD_{i,s,r,t} - DD_{i,s,r,t,ref}.L] \quad (66)$$

Figure 2 : Demand by geographic origin[4]



2.4.5 Demand for transportation services

The volume of transportation $Tr_{i,s,r,t}$ required to move commodity *i* imported by region *r* from region *s* is a fixed proportion $MUO_{i,s,r}$ of total imports $TRADE_{i,s,r,t}$.

$$Tr_{i,s,r,t} = MUO_{i,s,r}\, TRADE_{i,s,r,t} \quad (67)$$

Transportation demand per mode, $TrMode_{Transport,i,s,r,t}$, is then determined as being a fixed share $a^{Tr}_{Transport,i,s,r}$ of total transportation demand. Implicitly, thus, total demand for transportation is a Cobb-Douglas type of

[4] The acronyms for the volume followed by its corresponding price appear in brackets.

function. Hence, the exact price formulation for the aggregated price of transportation, $PTr_{i,s,r,t}$, is the dual form of a Cobb-Douglas.

$$PTrMode_{Transport,t}\, TrMode_{Transport,i,s,r,t} = a^{Tr}_{Transport,i,s,r,t}\, Tr_{i,s,r,t}\, PTr_{i,s,r,t} \quad (68)$$

$$PTr_{i,s,r,t} = \prod_{Transport} PTrMode^{a^{Tr}_{Transport,i,s,r}}_{Transport,t} \quad (69)$$

with

$PTrMode_{Transport,t}$ Price of transport per mode

$PTr_{i,r,s,t}$ Price of transportation by commodity and partners

2.5 Supply and market clearing

2.5.1 Transportation market

The world supply of transportation services per mode, $WorldTr_{Transport,t}$, follows a Cobb-Douglas specification. It follows that the supply from each region, $TrSupply_{Transport,r,t}$, is a constant share of the world value of transportation.

$$WorldTr_{Transport,t} = c^{T}_{Transport} \prod_{r} TrSupply^{a^{TrSupply}_{Transport,r}}_{Transport,r,t} \quad (70)$$

$$PY_{Transport,r,t}\left(1 + taxP_{Transport,r,t}\right) TrSupply_{Transport,r,t} = a^{TrSupply}_{Transport,r}\, PTrMode_{Transport,t}\, WorldTr_{Transport,t} \quad (71)$$

with

$c^{T}_{Transport}$ Scale coefficient

$a^{TrSupply}_{Transport,r}$ Share of each region in the world transport production

Market for transportation clears since demand of transportation is equal to supply. Equilibrium on the transportation market determines the world prices of transportation per mode, $PTrMode_{Transport,t}$.

$$WorldTr_{Transport,t} = \sum_{i,r,s} TrMode_{Transport,i,r,s,t} \quad (72)$$

2.5.2 Commodity market

In each region, supply of each commodity is equal to demand. Market clearing determines the price of each commodity, $PY_{i,r,t}$.

$$Y_{i,r,t} = D_{i,r,t} + \sum_{s} TRADE_{i,r,s,t} + TrSupply_{i,r,t} + Leon_{t} \quad (73)$$

With

$Leon_t$ Variable to check Walras condition

2.5.3 Factors of production market

2.5.3.1 Labor market

The mobility between rural and urban sectors in the dual (unskilled) labor market is determined through a CET function:

$$LGt_{Ltype,gender,r,t} = b^{Lt}_{Ltype,gender,r} Lbar_{gender,r,t} \left[\frac{WLGt_{Ltype,gender,r,t}}{WLG_{gender,r,t}}\right]^{sigma^L} \quad (74)$$

With

$b^{Lt}_{Ltype,gender,r}$ Labor scale coefficient

$sigma^L$ Labor elasticity

And the average wage of unskilled labor is given by:

$$WLG_{gender,r,t} * \bar{L}_{gender,r,t} = \sum_{Ltype} WLGt_{Ltype,gender,r,t} * LGt_{Ltype,gender,r,t} \quad (75)$$

The equilibrium wages for unskilled and skilled labor are given by:

$$LGt_{Ltype,gender,r,t} = \sum_{j\$Labor(j,Ltype)} LG_{gender,j,r,t} \quad (76)$$

$$\bar{H}_{gender,r,t} = \sum_j HG_{gender,j,r,t} \quad (77)$$

2.5.3.2 Land market

The spatial disaggregation of the model is implemented through the land market at the regional (AEZ) level, assuming homogenous production technology across regions. Land mobility across sectors is assumed to be imperfect. Land supply, $\overline{TE}_{mgmentld,r,z,t}$ behaves as an isoelastic function of the real return to land (Lee and Mensbrugghe, 2001)). This implies that the greater the real overall return to land, the greater will be the overall supply of land.

$$\overline{TE}_{mgmentld,AEZ,r,z,t} = \overline{TE}^O_{mgmentld,AEZ,r,t} \left(\frac{\overline{WTE}_{mgmentld,AEZ,r,t}}{PIndC_{r,t}}\right)^{\sigma^{Tebar}_{mgmentld,AEZ,r}} \quad (78)$$

with

$\overline{TE}^O_{mgmentld,AEZ,r,z}$ Benchmark value of total land supply in region z

$\overline{WTE}_{mgmentld,AEZ,r,t}$ Aggregate price for land in region z

$\sigma^{Tebar}_{mgmentld,AEZ,r}$ Total land supply elasticity

For the subset of fixed land supply, $\overline{TE}_{mgmentld,r,z,t} = \overline{TE}^O_{mgmentld,r,z}$.

To represent the imperfect mobility of land, supply to each activity, $TEZ_{mgmentld,i,AEZ,r,t}$, is determined following a CET aggregation. Landowners maximize their income subject to the CET aggregator, which leads to the following first order condition:

$$TEZ_{mgmentld,i,AEZ,r,t} = b^{TEZ}_{mgmentld,i,AEZ,r}\ \overline{TE}_{mgmentld,AEZ,r,t}\ \left(\frac{WTEZ_{mgmentld,i,AEZ,r,t}}{\overline{WTE}_{mgmentld,AEZ,r,t}}\right)^{\sigma^{TEZ}_{AEZ,r}} \quad (79)$$

with

$b^{TEZ}_{mgmentld,i,AEZ,r}$ Land scale coefficient

$\sigma^{TEZ}_{AEZ,r}$ Land elasticity

It follows that the aggregated price of land is a weighted sum of the price received in each activity.

$$\overline{WTE}_{mgmentld,AEZ,rt}\ \overline{TE}_{mgmentld,AEZ,r,t} = \sum_i WTEZ_{mgmentld,i,AEZ,r,t} * TEZ_{mgmentld,i,AEZ,r,t} \quad (80)$$

The aggregate land price for commodity i is given by:

$$TE_{i,r,t} * WTE_{i,r,t} = \sum_{AEZ,mgmentld} WTEZ_{mgmentld,i,AEZ,r,t} * TEZ_{mgmentld,i,AEZ,r,t} \quad (81)$$

And the aggregate land supply for commodity i:

$$TEZ_{mgmentld,i,AEZ,r,t} = b^{TE}_{mgmentld,i,AEZ,r}\ \frac{TE_{i,r,t}}{LandUseintensity_{i,r,t}}\left(\frac{WTEZ_{mgmentld,i,AEZ,r,t}}{WTE_{i,r,t}}\right)^{\sigma^{TE}_{i,r}} \quad (82)$$

With

$b^{TE}_{mgmentld,i,AEZ,r}$ AEZ relative productivity for commodity i

$LandUseintensity_{i,r,t}$ Land Use Intensity

$\sigma^{TE}_{i,r}$ Land elasticity across AEZ

2.5.3.3 Capital market

At each period, the capital stock invested by region *s* in activity *j* in region *r*, $K_{j,s,r,t}$, is given by the depreciated stock of capital inherited from the preceding period plus new investment $INV_{j,s,r,t}$

$$K_{j,s,r,t} = K_{-j,s,r,t}(1-\delta_r) + INV_{j,s,r,t} \quad (83)$$

with

δ_r Depreciation rate

Where the investment per activity and region of destination depends on the rate of return to capital, the aggregated price of new capital and capital stock[5].

[5] For a complete discussion on the investment behaviour, see Decreux and Valin (2007).

$$INV_{j,s,r,t} = B_{s,t}\, a_{j,s,r}\, KTOT_{j,r,t}\, e^{\alpha\left(\frac{WK_{j,r,t}}{PINVTOT_{r,t}}\right)} \quad (84)$$

with

$B_{s,t}$	Scale coefficient for investment
$a_{j,s,r}$	Investment scale coefficient
α	Elasticity of investment to return on capital

Total investment made in region r, $INVTOT_{r,t}$, is simply the sum of investment made in each sector of each region:

$$INVTOT_{r,t} = \sum_{j,s} INV_{j,s,r,t} \quad (85)$$

In each sector, total supply of capital equals demand, which determines the rate of return to capital specific to this sector ($WK_{i,r,t}$).

$$KTOT_{i,r,t} = \sum_{s} K_{i,s,r,t} \quad (86)$$

The average rate of return in the economy, $\overline{WK}_{r,t}$, is given by:

$$\overline{WK}_{r,t} * \sum_{j} KTOT_{j,r,t} = \sum_{j} KTOT_{j,r,t} * WK_{j,r,t} \quad (87)$$

2.6 Macroeconomic constraints

In each region, total investment must be equal to total savings:

$$SAVH_{r,t} + SAVG_{r,t} - \sum_{i,s} PINVTOT_{s,t}\, INV_{i,r,s,t} = CAB_{r,t} + Remittances_{r,t} \quad (88)$$

Where $CAB_{r,t}$ represents the current account balance, which is a constant share $SOLD_{r,t}$ of GDP, $GDPMP_{r,t}$.

$$CAB_{r,t} = GDPMP_{r,t_t} * SOLD_{rnot\in surplus(r),t} * SCAB_t + GDPMP_{r,t_t} * SOLD_{r\in surplus(r),t} \quad (89)$$

With

$SCAB_t$	A scaling factor for countries not in surplus
$surplus(r)$	Countries in surplus

Bilateral remittances are given by:

$$REM_{r,s,t} = REMO_{r,s} * ShiftMigrants_{r,s,t} * \frac{\sum_{gender} WLG_{gender,r,t} * \bar{L}_{gender,r,t}}{\sum_{gender} WLGO_{gender,r} * \overline{LO}_{gender,r}} \quad (90)$$

With

$ShiftMigrants_{r,s,t}$	Parameter to authorize bilateral migrant population shift

While the net remittances are given by:

$$Remittances_{r,t} = \sum_s REM_{s,r,t} - \sum_s REM_{r,s,t} \quad (91)$$

With

$REM_{s,r,t}$ Bilateral remittances

The balance of global savings is given by:

$$\sum_r \left(CAB_{r,t} + Remittances_{r,t}\right) = 0 \quad (92)$$

Thus, the sum of current account balances and remittances should be zero at the world level

The trade balance for goods and services is determined by:

$$SOLD_{TRADE\,CategoryTrade,r,t} = \{\sum_{s,i\$services(i)}[PY_{i,r,t}(1 + taxEXP_{i,r,t} + taxAMF_{i,r,t})(1 + taxP_{i,r,t}) * TRADE_{i,r,s,t} - PCIF_{i,s,r,t} * TRADE_{i,s,r,t} + \sum_{Transport} PY_{Transport,r,t}(1 + taxP_{Transport,r,t})TrSupply_{Transport,r,t}]\}\$sameas(CategoryTrade,Services) + \{\sum_{s,i\$not\ services(i)}[PY_{i,r,t}(1 + taxEXP_{i,r,t} + taxAMF_{i,r,t})(1 + taxP_{i,r,t}) * TRADE_{i,r,s,t} - PCIF_{i,s,r,t} * TRADE_{i,s,r,t}]\}\$sameas(CategoryTrade, Goods) \quad (93)$$

World (FOB) prices are given by:

$$WorldPrices_{i,t} = \frac{\sum_{s,r} TRADEO_{i,s,r} * PY_{i,s,t}(taxP_{i,r,t})(1+taxEXP_{i,s,r,t}+taxAMF_{i,s,r,t})}{\sum_{s,r} TRADEO_{i,s,r} * PYO_{i,s}(taxPO_{i,r})(1+taxEXPO_{i,s,r}+taxAMFO_{i,s,r})} \quad (94)$$

Consistent with the system of national accounting, each region's GDP at market prices is given by the sum of payments to factors of production and of indirect taxes.

$$GDPMP_{r,t} = \sum_j PL_{j,r,t}\, L_{j,r,t} + PTE_{j,r,t}\, TE_{j,r,t} + PRN_{j,r,t}\, RN_{j,r,t} + PH_{j,r,t}\, H_{j,r,t} + PK_{j,r,t}\, KTOT_{j,r,t} + \sum_i \{RECPROD_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t}\} + RECDIR_{r,t} + (1 - TariffEfficiency_{r,t}) * \sum_{s,i} PCIF_{i,s,r,t} * DD_{i,s,r,t} * TRADE_{i,s,r,t} \quad (95)$$

World nominal GDP, $PIBMVAL_t$, is the simply the sum of regional GDPs, $GDPMP_{r,t}$:

$$PIBMVAL_t = \sum_r GDPMP_{r,t} \quad (96)$$

The real world GDP, $WorldGDP_t$, is given by:

$$WorldGDP_t = \sum_r \frac{GDPVOL_{r,t}}{GDPVOLO_{r,t}} GDPMPO_{r,t} \quad (97)$$

Real GDP, $GDPVOL_{r,t}$, is computed by dividing GDP at market prices by the consumer price index:

$$GDPVOL_{r,t} = \frac{GDPMP_{r,t}}{PIndC_{r,t}} \quad (98)$$

Total factor productivity is computed at the sectoral level in the baseline via:

$$PGFI_{i,r,t} = \left(PGF_{r,t} - 1\right) * FactorPGFI_{i,r,t} + 1 \quad (99)$$

With

$PGFI_{i,r,t}$	Sectoral (i) total factor productivity
$PGF_{r,t}$	Economy-wide total factor productivity
$FactorPGFI_{i,r,t}$	Default productivity shifter for baseline

Finally, an equation is introduced to allow the endogenous calibration of land productivity ($Yield_{i,r,t}$) to target yields indexes:

$$Yield_{i,r,t} * TE_{i,r,t} * YO_{i,r} = Y_{i,r,t} * TEO_{i,r} \quad (100)$$

2.7 Long run module

The specification of the model allows the user to select his own long run closure for capital markets. If the module is activated ($SET LT 1), then capital markets are integrated with a uniform rate of return, $WKUNI_{r,t}$. A set of two equations then determines the market:

$$WKUNI_{r,t} = WK_{j,r,t} \quad (101)$$

$$KTOTR_{r,t} = \sum_i K_{-i,r,r,t} \quad (102)$$

2.8 Factors market integration module

The user has the possibility to go one step further ahead and select a full market integration (labor, capital, and a consolidated current account balance with a homogenous CPI) at the Regional economic community (REC) level. If this option is activated ($SET MKTI 1), the following equations determine the integrated market variables.

$$PIndexDEMTOT_{r,t} = \sqrt{\left[\frac{\sum_i DEMTOTO_{i,r} PDEMTOT_{i,r,t}}{\sum_i DEMTOTO_{i,r} PDEMTOTO_{i,r}}\right] \left[\frac{\sum_i DEMTOT_{i,r,t} PDEMTOT_{i,r,t}}{\sum_i DEMTOT_{i,r,t} PDEMTOTO_{i,r}}\right]} \quad (103)$$

$$SOLD\_REC_{REC,t} * \sum_{r\$REC\_R(REC,R)} GDPM_{r,t} = \sum_{r\$REC\_R(REC,R)} CAB_{r,t} \quad (104)$$

$$P\_REC_{REC,t} = PIndexDEMTOT_{r,t} \quad (105)$$

With

$PIndexDEMTOT_{r,t}$	Price index on PDEMTOT
$P\_REC_{REC,t}$	Average Price in the Active REC
$SOLD\_REC_{REC,t}$	Sold of the REC

For labor markets we have:

$$\overline{LG\_REC}_{gender,REC,t} = \sum_{r\$REC\_R(REC,R)} \overline{L}_{gender,r,t} \quad (106)$$

$$WLG\_REC_{gender,REC,t} = WLG_{gender,r,t} \quad (107)$$

$$\overline{HG\_REC}_{gender,REC,t} = \sum_{r\$REC\_R(REC,R)} \overline{H}_{gender,r,t} \quad (108)$$

$$WHG\_REC_{gender,REC,t} = WHG_{gender,r,t} \quad (109)$$

With

$WHG\_REC_{gender,REC,t}$	Wages (skilled labor) in the integrated market
$WLG\_REC_{gender,REC,t}$	Wages (unskilled labor) in the integrated market
$\overline{HG\_REC}_{gender,REC,t}$	Total Skilled labor stock for the REC
$\overline{LG\_REC}_{gender,REC,t}$	Total Unskilled labor stock for the REC

And for the capital market:

$$\overline{K\_REC}_{REC,t} = \sum_{r\$REC\_R(REC,R)} KTOTR_{r,t} \quad (110)$$

$$WK\_REC_{REC,t} = WKUNI_{r,t} \quad (111)$$

With

$\overline{K\_REC}_{REC,t}$	Total stock of capital for the REC
$WK\_REC_{REC,t}$	Capital Return in the integrated market

2.9 Optimal tariff bands module

The endogenous (optimal) tariffs are determined through a welfare maximization process. Welfare is defined here as the equivalent variation. Different options are available: the decision maker is either the region (REC) as a bloc (maximization of regional welfare) or a country which maximizes its own welfare and whose choice is applied to the whole region (delegation).

The endogenous tariffs are defined by:

$$DD_{i,r,s,t} = \sum_{(BAND\_SET,REC)\$REC\_R(REC,S)} CET\_weights_{i,r,s,BAND\_SET} * TariffBandREC_{BAND\_SET,REC,t} \quad (112)$$

With

$TariffBandREC_{BAND\_SET,REC,t}$	Value of tariffs in the various bands
$CET\_weights_{i,r,s,BAND\_SET}$	Common External Tariffs weights

The maximization of the welfare (here the equivalent variation, $VarEq_{r,t}$) by the decision maker, $DecisionMaker(r)$, follows the below steps.

First, we compute the consumption for commodity i, $VEQCH_{i,r,t}$, and AGI groups, $VEQCHC_{AGI,r,t}$, necessary for computing the equivalent variation:

$$VEQCHC_{AGI,r,t} = Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} * \left(cmin_{AGI,r,t} + a_{AGI,r,t}^{CC} \, AUX_{r,t} \left(\frac{VEQP_{r,t}}{VEQPCC_{AGI,r,t}} \right)^{\sigma_{r,t}^{CC}} \right) \quad (113)$$

$$VEQCH_{i,r,t} = a_{i,r,t}^{C} * \sum_{AGI\$mapAGI(i,AGI)} VEQCHC_{AGI,r,t} * \left[\frac{\sum_{AGI\$mapAGI(i,AGI)} VEQPCC_{AGI,r,t}}{PC.L_{i,r,t,ref}} \right]^{\sum_{AGI\$mapAGI(i,AGI)} \sigma_{r,AGI,t}^{C}} \quad (114)$$

Then we compute the price indexes for AGI groups, $VEQPCC_{AGI,r,t}$, and for utility, $VEQP_{r,t}$.

$$VEQP_{r,t} * AUX_{r,t} = \sum_{AGI} VEQPCC_{AGI,r,t} \left(\frac{VEQCHC_{AGI,r,t}}{Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t}} - cmin_{AGI,r,t} \right) \quad (115)$$

$$VEQPCC_{AGI,r,t} * VEQCHC_{AGI,r,t} = \sum_{i\$mapAGI(i,AGI)} PC.L_{i,r,t,ref} * VEQCH_{i,r,t} \quad (116)$$

In the penultimate step we compute the utility target for equivalent variation,

$$VarEq_{r,t,sim} = \sum_{i} PC.L_{i,r,t,ref} * \left(VEQCH_{i,r,t} - CH.L_{i,r,t,ref} \right) \quad (117)$$

Finally, we maximize the welfare of the decision maker ($Objectif$):

$$Objectif = \sum_{(r,t)\$DecisionMaker(r)} VarEq_{r,t} \quad (118)$$

2.10 Economic Closures

In MIRAGRODEP, every economic agent balances income and expenditures: income of households equals to spending of households (consumption, savings and transfers), firms' spending (including payment to capital) equals firms' revenue. At a global level, savings must be equal to investment. At the country level, a gap between the two variables can occur due to international capital movements. Nevertheless, constraints on current account surplus or deficits are also considered, leading to real exchange rate adjustments (determining relative international prices among economies). Furthermore, supply equals demand for all commodities and factors in the economy.

More specifically, the following assumptions are made regarding the savings-investment balance, the public closure and the current account balance.

For this example, the so-called Neo-Classical closure is adopted: the marginal propensity to save is constant such that variations in income lead to variations in savings, which lead to variations in investment. Thus, investment is "savings driven."

Regarding the public closure, when implementing a scenario, the user has the choice between 6 options:

- A Cobb Douglas public demand and real public expenses per head vary and adjust to variation in public revenues such that the ratio public deficit / GDP is constant
- no variation in real public expenses per head and a lumpsum tax is levied such that the ratio public deficit / GDP is constant
- no variation in real public expenses per head and a consumption tax is levied such that the ratio public deficit / GDP is constant
- no variation in real public expenses per head and an income tax is levied such that the ratio public deficit / GDP is constant
- A Cobb Douglas public demand and a lumpsum tax is levied such that the ratio public deficit / GDP is constant
- A Cobb Douglas public demand and a consumption tax is levied such that the ratio public deficit / GDP is constant

The choice of either option is not neutral and particularly important when it comes to welfare analysis. In order not to bias the welfare results a closure with no variation in real public expenses per head and a lumpsum tax (not distortive) levied to maintain the ratio public deficit / GDP constant should be preferred.

Finally, we assume in MIRAGRODEP that the current account balance is fixed (in the model, this is expressed as a percent of GDP at market price). The fixed level of the current account balance is maintained through an adjustment of the real exchange rate. With this specification, there is no "free lunch;" if a country needs to increase its imports, it will have to increase its exports as well through a depreciation of its real exchange rate. In doing so we avoid biased welfare analysis, where the country's consumption, and welfare, is "subsidized" through transfers from the rest of the world (capital inflows).

3. Running the model

Using MIRAGRODEP for policy analysis requires a number of steps the user need to follow strictly so that the model can run properly. It is important to follow the indicated sequence, otherwise a bug will occur. Also, not all the files have to be modified by the user.

First, the aggregation levels for products and regions have to be defined in the Aggregation.xlsx file. Once this is done, the AggregationGTAP.gms file must be run to execute the selected aggregation. After the aggregation done, the user needs to define in options.gms file the first and last year of the simulation and the choice for the public closure.

Once all the options are selected, running a simulation involves the execution of three (3) files in the following order[6:]

MSD.gms: the core model file, solves for the first year and includes the calibration file (Calib.gms)

Ref.gms: the file for the reference (baseline) scenario

simul_OptimaCET.gms: the simulation file

The execution sequence is managed by GAMS save and restarts functions that reduce considerably the amount of work when working with large models. In the example, all the files are run together using master_file.gms[7]. To do so, the user needs to specify (select) the value of the control variables which define the options:

- AGG: for the selected aggregation (up to the user)
- LT: for the long-term closure of the capital market (either 0 or 1)
- MKTI: for the factors market integration and current account balance consolidation option (either 0 or 1)
- PUBC: for the public closure (either 0,1,2,3,4,or 5)[8]
- REC: the relevant REC, here EAC.

When all the options are defined, the Master_file.gms can be run and the results are stored in a gdx file in the results\summary folder.

[6] All the other files must remain unchanged.
[7] The results at each stage are stored in a gdx file.
[8] See options.gms for the definition of each of the closures

Summary of Model Structure

Table 1 : Equations of MIRAGRODEP

Production		
First level: Leontief		GAMS
1.	$Y_{j,r,t} = a_{j,r}^{VA} * \left(1 - IceTr_{j,r,t}\right) * MFPI_{j,r,t} * VA_{j,r,t}$	EQ_VA
2.	$Y_{j,r,t} = a_{j,r}^{CNTER} * \left(1 - IceTr_{j,r,t}\right) * MFPI_{j,r,t} * \ CNTER_{j,r,t}$	EQ_CNTER
3.	$PY_{j,r,t}\ Y_{j,r,t} = PVA_{j,r,t}\ VA_{j,r,t} + PCNTER_{j,r,t}\ CNTER_{j,r,t}$	EQ_Y
Second level – Value added: CES		GAMS
4.	$L_{j,r,t} = a_{j,r}^{L}\ VA_{j,r,t}\ PGFI_{j,r,t}^{\sigma_j^{VA}-1} \left(\frac{PVA_{j,r,t}}{PL_{j,r,t}}\right)^{\sigma_j^{VA}}$	EQ_L
5.	$LG_{gender,j,r,t} = a_{gender,j,r}^{LG} L_{j,r,t} \left(\frac{PL_{j,r,t}}{PLG_{gender,j,r,t}}\right)^{\sigma_{unsklab,j,r}^{gender}}$	EQ_LG
6.	$PL_{j,r,t} * L_{j,r,t} = \sum_{gender} LG_{gender,r,j,t} * PLG_{gender,r,j,t}$	EQ_PL
7.	$TEIC_{j,r,t} = a_{j,r}^{TEIC} \cdot VA_{j,r,t} \cdot \left(\frac{PVA_{j,r,t}}{PTEIC_{j,r,t}}\right)^{\sigma_j^{VA}}$	EQ_TEIC
8.	$ICTE_{j,r,t} = a_{j,r}^{ICTE} \cdot TEIC_{j,r,t} \cdot \left(\frac{PTEIC_{j,r,t}}{PICTE_{j,r,t}}\right)^{\sigma_{j,r}^{TEIC}}$	EQ_ICTE
9.	$TE_{j,r,t} = a_{j,r}^{TE} * TEIC_{j,r,t} * \left[\left(PGFI_{j,r,t} - 1\right) * TE_{j,r,t}^{productivity} + 1\right]^{\sigma_{j,r}^{TEIC}-1} \cdot \left(\frac{PTEIC_{j,r,t}}{PTE_{j,r,t}}\right)^{\sigma_{j,r}^{TEIC}}$	EQ_TE
10.	$RN_{j,r,t} = a_{j,r}^{RN} \cdot VA_{j,r,t} \cdot PGFI_{r,t}^{\sigma_j^{VA}-1} \left(\frac{PVA_{j,r,t}}{PRN_{j,r,t}}\right)^{\sigma_j^{VA}}$	EQ_RN

11.	$Q_{j,r,t} = a_{j,r}^{Q} \cdot VA_{j,r,t} \cdot PGFI_{r,t}^{\sigma_j^{VA}-1} \cdot \left(\frac{PVA_{j,r,t}}{PQ_{j,r,t}}\right)^{\sigma_j^{VA}}$	EQ_Q
12.	$PVA_{j,r,t}\, VA_{j,r,t} = PL_{j,r,t}\, L_{j,r,t} + PTEIC_{j,r,t}\, TEIC_{j,r,t} + PRN_{j,r,t}\, RN_{j,r,t} + PQ_{j,r,t}\, Q_{j,r,t}$	EQ_PVA
13.	$PTEIC_{j,r,t} TEIC_{j,r,t} = PTE_{j,r,t} TE_{j,r,t} + PICTE_{j,r,t} ICTE_{j,r,t}$	EQ_PTEIC
14.	$PLG_{gender,j,r,t} = [\sum_{Ltype} WLGt_{Ltypegender,r,t}] (1 + taxf_{UnSkLab,j,r,t}^{VAL}) + PIndC_{r,t}\, taxf_{UnSkLab,j,r,t}^{VOL}$	EQ_PLG
15.	$PTE_{j,r,t} = WTE_{j,r,t} \left(1 + taxf_{Land,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{Land,j,r,t}^{VOL}$	EQ_PTE
16.	$PRN_{j,r,t} = WRN_{j,r,t} \left(1 + taxf_{NatlRes,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{NatlRes,j,r,t}^{VOL}$	EQ_PRN
Third level – Capital-Skilled labor bundle: CES		GAMS
17.	$H_{j,r,t} = a_{j,r}^{H}\, Q_{j,r,t} \left(\frac{PQ_{j,r,t}}{PH_{j,r,t}}\right)^{\sigma_j^{CAP}}$	EQ_H
18.	$HG_{gender,j,r,t} = a_{gender,j,r}^{HG} H_{j,r,t} \left(\frac{PH_{j,r,t}}{PHG_{gender,j,r,t}}\right)^{\sigma_{sklab,j,r}^{gender}}$	EQ_HG
19.	$PH_{j,r,t} H_{j,r,t} = \sum_{gender} PHG_{gender,j,r,t} HG_{gender,j,r,t}$	EQ_PH
20.	$KTOT_{j,r,t} = a_{j,r}^{K}\, Q_{j,r,t} \left(\frac{PQ_{j,r,t}}{PK_{j,r,t}}\right)^{\sigma_j^{CAP}}$	EQ_KTOT
21.	$PQ_{j,r,t}\, Q_{j,r,t} = PK_{j,r,t}\, KTOT_{j,r,t} + PH_{j,r,t}\, H_{j,r,t}$	EQ_PQ
22.	$PHG_{gender,j,r,t} = WHG_{gender,r,t} \left(1 + taxf_{SkLab,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{SkLab,j,r,t}^{VOL}$	EQ_PHG
23.	$PK_{j,r,t} = WK_{j,r,t} \left(1 + taxf_{Capital,j,r,t}^{VAL}\right) + PIndC_{r,t}\, taxf_{Capital,j,r,t}^{VOL}$	EQ_PK

Second level – Intermediate consumption: CES		GAMS
24.	$IC_{i,j,r,t} = \left[a_{i,j,r}^{IC} (1 + TrTCost_{i,j,r,t})^{\sigma_j^{IC}-1} CNTER_{j,r,t} \left(\frac{PCNTER_{j,r,t}}{PIC_{i,j,r,t}} \right)^{\sigma_j^{IC}} \right] \$not\ map_{i,j,r}^{TEIC} + \left[a_{i,j,r}^{IC} (1 + TrTCost_{i,j,r,t})^{\sigma_j^{ICTE}-1} ICTE_{j,r,t} \left(\frac{PICTE_{j,r,t}}{PIC_{i,j,r,t}} \right)^{\sigma_j^{ICTE}} \right] \$map_{i,j,r}^{TEIC}$	EQ_IC
25.	$PCNTER_{j,r,t}\ CNTER_{j,r,t} = \sum_{i\$not\ map_{i,j,r}^{TEIC}} PIC_{i,j,r,t}\ IC_{i,j,r,t}$	EQ_PCNTER
26.	$PICTE_{j,r,t}\ ICTE_{j,r,t} = \sum_{i\$map_{i,j,r}^{TEIC}} PIC_{i,j,r,t}\ IC_{i,j,r,t}$	EQ_PICTE
27.	$PIC_{i,j,r,t} = PDEMTOT_{i,r,t}\ (1 + taxicc_{i,j,r,t})$	EQ_PIC
Income and Savings		
Households		GAMS

28.	$$REVH_{r,t} = \sum_j \left\{ WRN_{j,r,t}\, RN_{j,r,t} + WTE_{j,r,t} \cdot TE_{j,r,t} + \sum_s WK_{j,s,t}\, K_{j,r,s,t} \right\} + Shiftpop_{poptotal,r,t} Population_{poptotal,r,t} TRH_{r,t}\, PIndC_{r,t} - Shiftpop_{poptotal,r,t} Population_{poptotal,r,t} lumpsum_{r,t} + (1 - TaxEfficiency_{r,t}) \left\{ \left[\sum_i RECPROD_{i,r,t} + RECFAC_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t} \right] + RECDIR_{r,t} \right\} + (1 - TariffEfficiency_{r,t}) \left[\sum_{s,i} PCIF_{i,s,r,t} DD_{i,s,r,t} TRADE_{i,s,r,t} \right] + \sum_{gender} WHG_{gender,r,t} \bar{H}_{gender,r,t} + WLG_{gender,r,t} \bar{L}_{gender,r,t}$$	EQ_REVH
29.	$$SAVH_{r,t} = epa_r \left(REVH_{r,t} - RECDIR_{r,t} - \sum_s REM_{r,s,t} + \sum_s REM_{s,r,t} \right)$$	EQ_SAVH
30.	$$BUDH_{r,t} = REVH_{r,t} - SAVH_{r,t} - RECDIR_{r,t} - \sum_s REM_{r,s,t} + \sum_s REM_{s,r,t}$$	EQ_BUDH
Government		GAMS
31.	$$REVG_{r,t} = TaxEfficiency_{r,t} * \sum_i \{ RECPROD_{i,r,t} + RECFAC_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t} \} + RECDIR_{r,t} + Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} * lumpsum_{r,t}$$	EQ_REVG
32.	$$RECPROD_{i,r,t} = taxP_{i,r,t}\, PY_{i,r,t}\, Y_{i,r,t}$$	EQ_RECPROD

33.	$RECFAC_{j,r,t}$ $= PIndC_{r,t}\,[taxf^{VOL}_{Land,j,r,t}\,TE_{j,r,t}$ $+\left(\sum_{gender} taxf^{VOL}_{Sklab,j,r,t} HG_{gender,j,rt} + taxf^{VOL}_{UnSklab,j,r,t} LG_{gender,j,rt}\right)$ $+ taxf^{VOL}_{NatlRes,j,r,t}\,RN_{j,r,t} + taxf^{VOL}_{Capital,j,r,t}\,KTOT_{j,r,t}]$ $+ taxf^{VAL}_{Land,j,r,t}\,WTE_{j,r,t}\,TE_{j,r,z,t}$ $+ \sum_{gender} taxf^{VAL}_{Sklab,j,r,t} WHG_{gender,j,r,t} HG_{gender,j,rt} + taxf^{VAL}_{UnSklab,j,r,t}$ $* \sum_{Ltype} WLGt_{Ltype,gender,r,t} LG_{gender,j,r,t}$ $+ taxf^{VAL}_{NatlRes,j,r,t}\,WRN_{j,r,t}\,RN_{j,r,t} + taxf^{VAL}_{Capital,j,r,t}\,WK_{j,r,t}\,KTOT_{j,r,t}$	EQ_RECFAC
34.	$RECEXP_{i,r,t} = PY_{i,r,t}\,(1 + taxP_{i,r,t})\sum_{s}(taxEXP_{i,r,s,t} + taxAMF_{i,r,s,t})TRADE_{i,r,s,t}$	EQ_RECEXP
35.	$RECDD_{i,r,t} = TariffEfficiency_{r,t} * \sum_{s} DD_{i,s,r,t}\,PCIF_{i,s,r,t}\,TRADE_{i,s,r,t}$	EQ_RECDD
36.	$RECCONS_{i,r,t} = PDEMTOT_{i,r,t}\left\{(taxcc_{i,r,t} + addtaxcc_{r,t})\,CH_{i,r,t} + (taxgc_{i,r,t} + addtaxcc_{r,t})CG_{i,r,t} + (taxkgc_{i,r,t} + addtaxcc_{r,t})\,KG_{i,r,t} + \sum_{j} taxicc_{i,j,r,t}\;IC_{i,j,r,t}\right\}$	EQ_RECCONS
37.	$RECDIR_{r,t} = [taxdir_{r,t} + addtaxdir_{r,t}]\,REVH_{r,t}$	EQ_RECDIR
38.	$SAVG_{r,t} = PUBSOLD_{r}\,GDPMP_{r,t}$	EQ_SAVG
39.	$BUDG_{r,t} = \sum_{i} PCG_{i,r,t} CG_{i,r,t} + Realbudget\_pc_{r} \prod_{i} PC_{i,r,t}{}^{\alpha\_g_{i,r}} * Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t}$	EQ_BUDG

40.	$BUDG_{r,t} = REVG_{r,t} - SAVG_{r,t} - Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} * TRH_{r,t} * PIndC_{r,t}$	EQ_comptax
Demand		
41.	$DEMTOT_{i,r,t} = CH_{i,r,t} + CG_{i,r,t} + \sum_{j} IC_{i,j,r,t} + KG_{i,r,t}$	EQ_DEMTOT
Private demand		GAMS
42.	$CHC_{AGI,r,t} = Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} \left(cmin_{AGI,r,t} + a_{AGI,r}^{CC} AUX_{r,t} \left(\frac{P_{r,t}}{PCC_{AGI,r,t}} \right)^{\sigma_{r,t}^{CC}} \right)$	EQ_CHC
43.	$CH_{i,r,t} = a_{i,r,t}^{C} * \sum_{AGI\$mapAGI(i,AGI)} CHC_{AGI,r,t} * \left[\frac{\sum_{AGI\$mapAGI(i,AGI)} PCC_{AGI,r,t}}{PC_{i,r,t}} \right]^{\sum_{AGI\$mapAGI(i,AGI)} \sigma_{r,AGI,t}^{C}}$	EQ_CH
44.	$BUDH_{r,t} = \sum_{i} PC_{i,r,t} CH_{i,r,t}$	EQ_AUX
45.	$P_{r,t} AUX_{r,t} = \sum_{AGI} PCC_{AGI,r,t} \left(\frac{CHC_{AGI,r,t}}{Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t}} - cmin_{AGI,r,t} \right)$	EQ_P
46.	$PC_{i,r,t} = PDEMTOT_{i,r,t} \left(1 + taxcc_{i,r,t} + addtaxcc_{r,t}\right)$	EQ_PC
47.	$PCC_{AGI,r,t} * CHC_{AGI,r,t} = \sum_{i\$mapAGI(i,AGI)} PC_i * CH_i$	EQ_PCC

48.	$PindC_{r,t} = \sqrt{\left[\frac{\sum_i PC_{i,r,t}\ CH^O_{i,r}}{\sum_i PC^O_{i,r}\ CH^O_{i,r}}\right]\left[\frac{\sum_i PC_{i,r,t}\ CH_{i,r,t}}{\sum_i PC^O_{i,r}\ CH_{i,r,t}}\right]}$	EQ_PIndC
Public demand		GAMS
49.	$CG_{i,r,t} = \alpha^G_{i,r}\ \frac{BUDG_{r,t}}{PCG_{i,r,t}}\$(pubclosure = \{0, or\ 4\ or\ 5)$ $+ \frac{CG0_{i,r} * Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t}}{* Shiftpop_{poptotal,r,t0,ref} * Population_{poptotal,r,t0}}\$(pubclosure \neq \{0,4,5\}$	EQ_CG
50.	$PCG_{i,r,t} = PDEMTOT_{i,r,t}\left(1 + taxgc_{i,r,t} + addtaxcc_{r,t}\right)$	EQ_PCG
Demand for investment purposes		GAMS
51.	$KG_{i,r,t} = a^{KG}_{i,r}\ INVTOT_{r,t}\left(\frac{PINVTOT_{r,t}}{PKG_{i,r,t}}\right)^{\sigma^{KG}}$	EQ_KG
52.	$PINVTOT_{r,t}\ INVTOT_{r,t} = \sum_i PKG_{i,r,t}\ KG_{i,r,t}$	EQ_PINVTOT
53.	$PKG_{i,r,t} = PDEMTOT_{i,r,t}\left(1 + taxkgc_{i,r,t} + addtaxcc_{r,t}\right)$	EQ_PKG
Demand by geographic origin		GAMS
54.	$D_{i,r,t} = a^D_{i,r}\ DEMTOT_{i,r,t}\left(\frac{PDEMTOT_{i,r,t}}{PD_{i,r,t}}\right)^{\sigma_i^{ARM}}$	EQ_D
55.	$M_{i,r,t} = a^M_{i,r}\ DEMTOT_{i,r,t}\left(\frac{PDEMTOT_{i,r,t}}{PM_{i,r,t}}\right)^{\sigma_i^{ARM}}$	EQ_M
56.	$PDEMTOT_{i,r,t}\ DEMTOT_{i,r,t} = PD_{i,r,t}\ D_{i,r,t} + PM_{i,r,t}\ M_{i,r,t}$	EQ_PDEMTOT
57.	$PD_{i,r,t} = PY_{i,r,t}\ (1 + taxP_{i,r,t})$	EQ_PD
58.	$ARM_{i,Arm1,r,t} = a^{ARM}_{i,Arm1,r}\ M_{i,r,t}\left(\frac{PM_{i,r,t}}{PARM_{i,Arm1,r,t}}\right)^{\sigma_{i,r}^{Arm1}}$	EQ_ARM

59.	$ARM_{i,Arm1,r,t} * PARM_{i,Arm1,r,t} = \sum_{s\$Armtree(i,r,s,Arm1)} PDEMA_{i,s,r,t} * DEMA_{i,s,r,t}$	EQ_PARM
60.	$DEMA_{i,s,r,t} = a_{i,s,r}^{IMP} * \sum_{Arm1} ARM_{i,Arm1,r,t} \left(\frac{\sum_{Arm1} PARM_{i,Arm1,r,t}}{PDEMA_{i,s,r,t}} \right)^{\sigma_{i,Arm1,r}^{IMP}}$	EQ_DEMA
61.	$PM_{i,r,t}\ M_{i,r,t} = \sum_{Arm1} ARM_{i,Arm1,r,t} * PARM_{i,Arm1,r,t}$	EQ_PM
62.	$PDEMA_{i,s,r,t} = PCIF_{i,s,r,t} \left(1 + DD_{i,s,r,t}^{A}\right)$	EQ_PDEMA
63.	$PCIF_{i,s,r,t} = PY_{i,s,t} \left(1 + taxEXP_{i,s,r,t} + taxAMF_{i,s,r,t}\right) (1 + taxP_{i,s,t}) + MUO_{i,s,r}\ PTr_{i,s,r,t}$	EQ_PCIF
64.	$PDEM_{i,s,r,t} = PCIF_{i,s,r,t}\left(1 + DD_{i,s,r,t}\right)$	EQ_PDEM
65.	$DEMA_{i,s,r,t}\ PDEMA_{i,s,r,t} = PDEM_{i,s,r,t}\ TRADE_{i,s,r,t}$	EQ_TRADE
66.	$DD_{i,s,r,t}^{A} = DD_{i,s,r,t,ref}^{A}.L + [DD_{i,s,r,t} - DD_{i,s,r,t,ref}.L]$	EQ_DDDDA
Demand for transportation services		GAMS
67.	$Tr_{i,s,r,t} = MUO_{i,s,r}\ TRADE_{i,s,r,t}$	EQ_Tr
68.	$PTrMode_{Transport,t}\ TrMode_{Transport,i,s,r,t} = a_{Transport,i,s,r,t}^{Tr}\ Tr_{i,s,r,t}\ PTr_{i,s,r,t}$	EQ_TrMode
69.	$PTr_{i,s,r,t} = \prod_{Transport} PTrMode_{Transport,t}^{a_{Transport,i,s,r}^{Tr}}$	EQ_PTr
Supply and market clearing		
Transportation market		GAMS
70.	$WorldTr_{Transport,t} = c_{Transport}^{T} \prod_{r} TrSupply_{Transport,r,t}^{a_{Transport,r}^{TrSupply}}$	EQ_WorldTr
71.	$PY_{Transport,r,t} \left(1 + taxP_{Transport,r,t}\right) TrSupply_{Transport,r,t} = a_{Transport,r}^{TrSupply}\ PTrMode_{Transport,t}\ WorldTr_{Transport,t}$	EQ_TrSupply

72.	$WorldTr_{Transport,t} = \sum_{i,r,s} TrMode_{Transport,i,r,s,t}$	EQ_PTrMode
Commodity market		GAMS
73.	$Y_{i,r,t} = D_{i,r,t} + \sum_{s} TRADE_{i,r,s,t} + TrSupply_{i,r,t} + Leon_{t}$	EQ_PY
Factors of production market		
Labor market		GAMS
74.	$LGt_{Ltype,gender,r,t} = b^{Lt}_{Ltype,gender,r} Lbar_{gender,r,t} \left[\frac{WLGt_{Ltype,gender,r,t}}{WLG_{gender,r,t}}\right]^{sigma^{L}}$	EQ_LGt
75.	$WLG_{gender,r,t} * \bar{L}_{gender,r,t} = \sum_{Ltype} WLGt_{Ltype,gender,r,t} * LGt_{Ltype,gender,r,t}$	EQ_WLG
76.	$LGt_{Ltype,gender,r,t} = \sum_{j\$Labor(j,Ltype)} LG_{gender,j,r,t}$	EQ_WLGt
77.	$\bar{H}_{gender,r,t} = \sum_{j} HG_{gender,j,r,t}$	EQ_WHG
Land market		GAMS
78.	$\overline{TE}_{mgmentld,AEZ,r,z,t} = \overline{TE}^{O}_{mgmentld,AEZ,r,t} \left(\frac{\overline{WTE}_{mgmentld,AEZ,r,t}}{PIndC_{r,t}}\right)^{\sigma^{Tebar}_{mgmentld,AEZ,r}}$	EQ_TEbar
79.	$TEZ_{mgmentld,i,AEZ,r,t} = b^{TEZ}_{mgmentld,i,AEZ,r} \overline{TE}_{mgmentld,AEZ,r,t} \left(\frac{WTEZ_{mgmentld,i,AEZ,r,t}}{\overline{WTE}_{mgmentld,AEZ,r,t}}\right)^{\sigma^{TEZ}_{AEZ,r}}$	EQ_WTEZ
80.	$\overline{WTE}_{mgmentld,AEZ,rt} \overline{TE}_{mgmentld,AEZ,r,t} = \sum_{i} WTEZ_{mgmentld,i,AEZ,r,t} * TEZ_{mgmentld,i,AEZ,r,t}$	EQ_WTEbar

81.	$TE_{i,r,t} * WTE_{i,r,t} = \sum_{AEZ,mgmentld} WTEZ_{mgmentld,i,AEZ,r,t} * TEZ_{mgmentld,i,AEZ,r,t}$	EQ_WTE
82.	$TEZ_{mgmentld,i,AEZ,r,t} = b^{TE}_{mgmentld,i,AEZ,r} \frac{TE_{i,r,t}}{LandUseintensity_{i,r,t}} \left(\frac{WTEZ_{mgmentld,i,AEZ,r,t}}{WTE_{i,r,t}}\right)^{\sigma^{TE}_{i,r}}$	EQ_TEZ
Capital market		GAMS
83.	$K_{j,s,r,t} = K_{-j,s,r,t}(1-\delta_r) + INV_{j,s,r,t}$	EQ_K
84.	$INV_{j,s,r,t} = B_{s,t}\, a_{j,s,r}\, KTOT_{j,r,t}\, e^{\alpha\left(\frac{WK_{j,r,t}}{PINVTOT_{r,t}}\right)}$	EQ_INV
85.	$INVTOT_{r,t} = \sum_{j,s} INV_{j,s,r,t}$	EQ_INVTOT
86.	$KTOT_{i,r,t} = \sum_{s} K_{i,s,r,t}$	EQ_WK
87.	$\overline{WK}_{r,t} * \sum_{j} KTOT_{j,r,t} = \sum_{j} KTOT_{j,r,t} * WK_{j,r,t}$	EQ_WKBAR
Macroeconomic constraints		
88.	$SAVH_{r,t} + SAVG_{r,t} - \sum_{i,s} PINVTOT_{s,t}\, INV_{i,r,s,t} = CAB_{r,t} + Remittances_{r,t}$	EQ_B
89.	$CAB_{r,t} = GDPMP_{r,t_t} * SOLD_{rnot\in surplus(r),t} * SCAB_t + GDPMP_{r,t_t} * SOLD_{r\in surplus(r),t}$	EQ_CAB
90.	$REM_{r,s,t} = REMO_{r,s} * ShiftMigrants_{r,s,t} * \frac{\sum_{gender} WLG_{gender,r,t} * \bar{L}_{gender,r,t}}{\sum_{gender} WLGO_{gender,r} * \overline{LO}_{gender,r}}$	Eq_REM
91.	$Remittances_{r,t} = \sum_{s} REM_{s,r,t} - \sum_{s} REM_{r,s,t}$	Eq_Remittances

92.	$\sum_r (CAB_{r,t} + Remittances_{r,t}) = 0$	Eq_GlobalSavings
93.	$SOLD_{TRADE\,CategoryTrade,r,t} = \{\sum_{s,i\$services(i)}[PY_{i,r,t}(1 + taxEXP_{i,r,t} + taxAMF_{i,r,t})(1 + taxP_{i,r,t}) * TRADE_{i,r,s,t} - PCIF_{i,s,r,t} * TRADE_{i,s,r,t} + \sum_{Transport} PY_{Transport,r,t}(1 + taxP_{Transport,r,t}) TrSupply_{Transport,r,t}]\}\$sameas(CategoryTrade,Services) + \{\sum_{s,i\$not\ services(i)}[PY_{i,r,t}(1 + taxEXP_{i,r,t} + taxAMF_{i,r,t})(1 + taxP_{i,r,t}) * TRADE_{i,r,s,t} - PCIF_{i,s,r,t} * TRADE_{i,s,r,t}]\}\$sameas(CategoryTrade, Goods)$	Eq_SOLD_TRADE
94.	$WorldPrices_{i,t} = \frac{\sum_{s,r} TRADEO_{i,s,r} * PY_{i,s,t}(taxP_{i,r,t})(1 + taxEXP_{i,s,r,t} + taxAMF_{i,s,r,t})}{\sum_{s,r} TRADEO_{i,s,r} * PYO_{i,s}(taxPO_{i,r})(1 + taxEXPO_{i,s,r} + taxAMFO_{i,s,r})}$	EQ_WorldPrices
95.	$GDPMP_{r,t} = \sum_j PL_{j,r,t}\, L_{j,r,t} + PTE_{j,r,t}\, TE_{j,r,t} + PRN_{j,r,t}\, RN_{j,r,t} + PH_{j,r,t}\, H_{j,r,t} + PK_{j,r,t}\, KTOT_{j,r,t} + \sum_i \{RECPROD_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t}\} + RECDIR_{r,t} + (1 - TariffEfficiency_{r,t}) * \sum_{s,i} PCIF_{i,s,r,t} * DD_{i,s,r,t} * TRADE_{i,s,r,t}$	EQ_GDPMP
96.	$PIBMVAL_t = \sum_r GDPMP_{r,t}$	EQ_PIBMVAL
97.	$WorldGDP_t = \sum_r \frac{GDPVOL_{r,t}}{GDPVOLO_{r,t}} GDPMPO_{r,t}$	EQ_WorldGDP
98.	$GDPVOL_{r,t} = \frac{GDPMP_{r,t}}{PIndC_{r,t}}$	EQ_PGF
99.	$PGFI_{i,r,t} = (PGF_{r,t} - 1) * FactorPGFI_{i,r,t} + 1$	EQ_PGFI
100.	$Yield_{i,r,t} * TE_{i,r,t} * YO_{i,r} = Y_{i,r,t} * TEO_{i,r}$	Eq_Yield
Long run module		
101.	$WKUNI_{r,t} = WK_{j,r,t}$	EQ_WKUNI

102.	$KTOTR_{r,t} = \sum_i K\_{i,r,r,t}$	EQ_KTOTR
Factors market integration module		
103.	$PIndexDEMTOT_{r,t} = \sqrt{\left[\frac{\sum_i DEMTOTO_{i,r} PDEMTOT_{i,r,t}}{\sum_i DEMTOTO_{i,r} PDEMTOTO_{i,r}}\right]\left[\frac{\sum_i DEMTOT_{i,r,t} PDEMTOT_{i,r,t}}{\sum_i DEMTOT_{i,r,t} PDEMTOTO_{i,r}}\right]}$	PIndexDEMTOT
104.	$SOLD\_REC_{REC,t} * \sum_{r\$REC\_R(REC,R)} GDPM_{r,t} = \sum_{r\$REC\_R(REC,R)} CAB_{r,t}$	EQ_CAB_REC
105.	$P\_REC_{REC,t} = PIndexDEMTOT_{r,t}$	EQ_P_REC
106.	$\overline{LG\_REC}_{gender,REC,t} = \sum_{r\$REC\_R(REC,R)} \bar{L}_{gender,r,t}$	EQ_LGBar_REC
107.	$WLG\_REC_{gender,REC,t} = WLG_{gender,r,t}$	EQ_WLG_REC
108.	$\overline{HG\_REC}_{gender,REC,t} = \sum_{r\$REC\_R(REC,R)} \bar{H}_{gender,r,t}$	EQ_HGBar_REC
109.	$WHG\_REC_{gender,REC,t} = WHG_{gender,r,t}$	EQ_WHG_REC
110.	$\overline{K\_REC}_{REC,t} = \sum_{r\$REC\_R(REC,R)} KTOTR_{r,t}$	EQ_KBar_REC
111.	$WK\_REC_{REC,t} = WKUNI_{r,t}$	EQ_WK_REC
Optimal tariffs bands module		
112.	$DD_{i,r,s,t} = \sum_{(BAND\_SET,REC)\$REC\_R(REC,S)} CET\_weights_{i,r,s,BAND\_SET} * TariffBandREC_{BAND\_SET,REC,t}$	EQ_DEFDD
113.	$VEQCHC_{AGI,r,t} = Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t} * \left(cmin_{AGI,r,t} + a^{CC}_{AGI,r,t}\, AUX_{r,t} \left(\frac{VEQP_{r,t}}{VEQPCC_{AGI,r,t}}\right)^{\sigma^{CC}_{r,t}} \right)$	EQ_VEQCHC

114.	$VEQCH_{i,r,t} = a^{C}_{i,r,t} * \sum_{AGI\$mapAGI(i,AGI)} VEQCHC_{AGI,r,t} * \left[\frac{\sum_{AGI\$mapAGI(i,AGI)} VEQPCC_{AGI,r,t}}{PC.L_{i,r,t,ref}}\right]^{\sum_{AGI\$mapAGI(i,AGI)} \sigma^{C}_{r,AGI,t}}$	EQ_VEQCH
115.	$VEQP_{r,t} * AUX_{r,t} = \sum_{AGI} VEQPCC_{AGI,r,t} \left(\frac{VEQCHC_{AGI,r,t}}{Shiftpop_{poptotal,r,t} * Population_{poptotal,r,t}} - cmin_{AGI,r,t}\right)$	EQ_VEQP
116.	$VEQPCC_{AGI,r,t} * VEQCHC_{AGI,r,t} = \sum_{i\$mapAGI(i,AGI)} PC.L_{i,r,t,ref} * VEQCH_{i,r,t}$	EQ_VEQPCC
117.	$VarEq_{r,t,sim} = \sum_{i} PC.L_{i,r,t,ref} * \left(VEQCH_{i,r,t} - CH.L_{i,r,t,ref}\right)$	EQ_VEQAUX
118.	$Objectif = \sum_{(r,t)\$DecisionMaker(r)} VarEq_{r,t}$	EQ_OBJ

Table 2 : Variables of MIRAGRODEP

Variable	Definition	GAMS
$addtaxdir_{r,t}$	Additional Income tax	addtaxdir(r,Temps,simul)
$addtaxcc_{r,t}$	Additional consumption tax	addtaxcc(r,Temps,simul)
$ARM_{i,Arm1,r,t}$	Armington aggregate first level	ARM(i,Arm1,r,Temps,simul)
$AUX_{r,t}$	Utility	AUX(r,Temps,simul)
$B_{r,t}$	Investment scale coefficient	B(r,Temps,simul)
$BUDG_{r,t}$	Budget allocated to public consumption	BUDG(r,Temps,simul)
$BUDH_{r,t}$	Budget allocated to private consumption	BUDH(r,Temps,simul)
$CAB_{r,t}$	Current account balance	CAB(r,temps,simul)
$CGi_{,r,t}$	Public consumption of commodity i	CG(i,r,Temps,simul)
$CH_{i,r,t}$	Consumption of commodity i by households	CH(i,r,Temps,simul)
$CHC_{AGI,r,t}$	Consumption of composite sector AGI by households	CHC(AGI,r,Temps,simul)
$CNTER_{j,r,t}$	Aggregate intermediate consumption by sector j	CNTER(j,r,Temps,simul)
$D_{i,r,t}$	Demand for domestic commodity i	D(i,r,Temps,simul)
$DEMA_{i,r,s,t}$	Bilateral trade from r to s (volume)	DEMA(i,r,s,Temps,simul)
$DEMTOT_{i,r,t}$	Total demand for composite commodity i	DEMTOT(i,r,Temps,simul)
$GDPMP_{r,t}$	Gross domestic product at market prices (nominal)	GDPMP(r,Temps,simul)
$GDPVOL_{r,t}$	Gross domestic product at market prices (real)	GDPVOL(r,Temps,simul)
$FactorPGFI_{i,r,t}$	Default productivity shifter for baseline	FactorPGFI(i,r,Temps,simul)
$H_{j,r,t}$	Demand for skilled labor by sector	H(j,r,Temps,simul)
$\bar{H}_{gender,r,t}$	Total skilled labor supply	Hbar(Gender,r,Temps,simul)

$HG_{gender,j,r,t}$	Demand for skilled labor by sector	HG(Gender,j,r,Temps,simul)
$\overline{HG\_REC}_{gender,REC,t}$	Total Skilled labor stock for the REC	HGBar_REC(Gender,REC, Temps, simul)
$IC_{i,j,r,t}$	Intermediate consumption of good i by sector j	IC(i,j,r,Temps,simul)
$ICTE_{j,r,t}$	Intermediate consumption bundle by sector j	ICTE(j,r,Temps,simul)
$INV_{j,s,r,t}$	Investment made by s in sector j of region r	INV(j,s,r,Temps,simul)
$INVTOT_{r,t}$	Total investment in region r	INVTOT(r,Temps,simul)
$K_{j,s,r,t}$	Capital stock invested by s in r	K(j,s,r,Temps,simul)
$K\_{j,s,r,t}$	Capital stock at the beginning of the period	K_(i,r,s,Temps,simul)
$\overline{K\_REC}_{REC,t}$	Total stock of capital for the REC	KBar_REC(REC,Temps, simul)
$KG_{i,r,t}$	Demand of good i for investment purposes	KG(i,r,Temps,simul)
$KTOT_{j,r,t}$	Capital stock available in sector j	KTOT(j,r,Temps,simul)
$KTOTR_{r,t}$	Stock of capital for long term closure	KTOTR(r,Temps,simul)
$L_{j,r,t}$	Demand for unskilled labor by sector j	L(j,r,Temps,simul)
$\bar{L}_{gender,r,t}$	Total supply of unskilled labor	Lbar(Gender,r,Temps,simul)
$LG_{gender,r,j,t}$	Demand for unskilled labor by sector j	LG(Gender,j,r,Temps,simul)
$\overline{LG\_REC}_{gender,REC,t}$	Total UnSkilled labor stock for the REC	LGBar_REC(Gender,REC,Temps,simul)
$LGt_{Ltype,gender,r,t}$	Supply of unskilled labor per type	LGt(Ltype,Gender,r,Temps,simul)
$lumpsum_{r,t}$	Lumpsum tax	lumpsum(r,Temps,simul)
$M_{i,r,t}$	Aggregate imports by region r	M(i,r,Temps,simul)
$Objectif$	Value of the objectif to maximize	$Objectif$
$P\_REC_{REC,t}$	Average Price in the Active REC	P_REC(REC,Temps,simul)
$P_{r,t}$	Price of utility	P(r,Temps,simul)

$PARM_{i,Arm1,r,t}$	Price of Armington aggregate first level	PARM(i,Arm1,r,temps,simul)
$PC_{i,r,t}$	Price of final private consumption	PC(i,r,Temps,simul)
$PCC_{AGI,r,t}$	Price of final private consumption for composite sectors	PCC(AGI,r,Temps,simul)
$PCG_{i,r,t}$	Price of final public consumption	PCG(i,r,Temps,simul)
$PCIF_{i,r,s,t}$	CIF price	PCIF(i,r,s,Temps,simul)
$PCNTER_{j,r,t}$	Price of aggregate intermediate consumption by sector j	PCNTER(j,r,Temps,simul)
$PD_{i,r,t}$	Price of for domestic good i (including taxes)	PD(i,r,Temps,simul)
$PDEM_{i,r,s,t}$	Price of bilateral trade from r to s	PDEM(i,r,s,Temps,simul)
$PDEMA_{i,r,s,t}$	Price of bilateral trade from r to s	PDEMA(i,r,s,Temps,simul)
$PDEMTOT_{i,r,t}$	Price of composite commodity i	PDEMTOT(i,r,Temps,simul)
$PGF_{r,t}$	Total factor productivity	PGF(r,Temps,simul)
$PGFI_{i,r,t}$	Sectoral TFP	PGFI(i,r,Temps,simul)
$PH_{j,r,t}$	Price of skilled labor (including taxes)	PH(j,r,Temps,simul)
$PHG_{gender,j,r,t}$	Price of skilled labor (including taxes)	PHG(Gender,j,r,Temps,simul)
$PIBMVAL_t$	World gross domestic product (value)	PIBMVAL(Temps,simul)
$PIC_{i,j,r,t}$	Price of intermediate consumption good i for sector j (including taxes)	PIC(i,j,r,Temps,simul)
$PICTE_{j,r,t}$	Price of intermediate consumption bundle for sector j (including taxes)	PICTE(j,r,Temps,simul)
$PIndC_{r,t}$	Consumer price index	PIndC(r,Temps,simul)
$PIndexDEMTOT_{r,t}$	Price index on PDEMTOT	PIndexDEMTOT(r,Temps,simul)
$PINVTOT_{r,t}$	Aggregate price of investment in region r	PINVTOT(r,Temps,simul)
$PK_{j,r,t}$	Price of capital (including taxes)	PK(j,r,Temps,simul)
$PKG_{i,r,t}$	Price of capital good consumption of good i (including taxes)	PKG(i,r,Temps,simul)

$PL_{j,r,t}$	Price of unskilled labor (including taxes)	`PL(j,r,Temps,simul)`
$PLG_{gender,r,j,t}$	Price of unskilled labor (including taxes)	`PLG(Gender,j,r,Temps,simul)`
$PM_{i,r,t}$	Price of aggregate imports	`PM(i,r,Temps,simul)`
$Population_{poptotal,r,t}$	Population	`Population("PopTotal",r,t)`
$PQ_{j,r,t}$	Price of capital - skilled labor aggregate	`PQ(j,r,Temps,simul)`
$PRN_{j,r,t}$	Price of natural resources (including taxes)	`PRN(j,r,Temps,simul)`
$PTE_{j,r,t}$	Average Price of land (including taxes)	`PTE(j,r,Temps,simul)`
$PTEIC_{j,r,t}$	Price of land (including taxes) and substituable inputs	`PTEIC(j,r,Temps,simul)`
$PTr_{i,r,s,t}$	Price of aggregate transport by export	`PTr(i,r,s,Temps,simul)`
$PTrMode_{j,t}$	World price of transport per mode	`PTrMode(j,Temps,simul)`
$PVA_{j,r,t}$	Price of value added	`PVA(j,r,Temps,simul)`
$PY_{j,r,t}$	Output price	`PY(j,r,Temps,simul)`
$Q_{j,r,t}$	Capital - skilled labor aggregate	`Q(j,r,Temps,simul)`
$Realbudget\_pc_r$	Real public expenses per capita	`RealBudg_pc(r)`
$RECCONS_{i,r,t}$	Consumption tax receipts	`RECCONS(i,r,Temps,simul)`
$RECDD_{i,r,t}$	Tariff revenues	`RECDD(i,r,Temps,simul)`
$RECDIR_{r,t}$	Tax receipts from direct taxation	`RECDIR(r,Temps,simul)`
$RECEXP_{i,r,t}$	Export tax receipts	`RECEXP(i,r,Temps,simul)`
$RECFAC_{j,r,t}$	Receipts from taxes on factors of production	`RECFAC(j,r,Temps,simul)`
$RECPROD_{i,r,t}$	Production tax receipts	`RECPROD(i,r,Temps,simul)`
$REM_{r,s,t}$	Bilateral Remittances	`REM(r,s,Temps,simul)`
$Remittances_{r,t}$	Net remittances	`Remittances(r,temps,simul)`

$REVG_{r,t}$	Government total income	REVG(r,Temps,simul)
$REVH_{r,t}$	Households income	REVH(r,Temps,simul)
$RN_{j,r,t}$	Demand for natural resources by sector	RN(j,r,Temps,simul)
$SAVG_{r,t}$	Government savings	SAVG(r,Temps,simul)
$SAVH_{r,t}$	Households savings	SAVH(r,Temps,simul)
$SCAB_t$	Scaling factor	SCAB(t,simul)
$SOLD_{r,t}$	Share of current account balance in world GDP	SOLD(r,Temps,simul)
$SOLD_{TRADE\,CategoryTrade,r,t}$	Trade surplus by category	SOLD_TRADE(CategoryTrade,r,t,sim)
$SOLD\_REC_{REC,t}$	Sold of the REC	SOLD_REC(REC,Temps, simul)
$TariffBandREC_{BAND\_SET,REC,t}$	Value of tariffs in the various bands	TariffBandREC(BAND_SET,REC, Temps,simul)
$TE_{j,r,t}$	Land used in sector j	TE(j,r,Temps,simul)
$\overline{TE}_{mgmentld,AEZ,r,z,t}$	Total land supply	TEbar(ManagementLand,AEZ,r,Temps,simul)
$\overline{TE}^{O}_{mgmentld,AEZ,r}$	Initial Total land supply	TEbarO(ManagementLand,AEZ,r)
$TEIC_{j,r,t}$	Land and substituable inputs	TEIC(j,r,Temps,simul)
$TEZ_{mgmentld,i,AEZ,r,t}$	Land use at the AEZ level	TEZ(ManagementLand,i,AEZ,r,Temps,simul)
$Tr_{i,r,s,t}$	Transport demand by export	Tr(i,r,s,Temps,simul)
$TRADE_{i,r,s,t}$	Bilateral trade from r to s (volume)	TRADE(i,r,s,Temps,simul)
$TRH_{r,t}$	Public transfers to households	TRH(r,Temps,simul)
$TrMode_{j,i,r,s,t}$	Transport demand by export, per mode	TrMode(j,i,r,s,Temps,simul)
$TrSupply_{j,r,t}$	Supply of international transportation by region r	TrSupply(j,r,Temps,simul)
$VA_{j,r,t}$	Value added	VA(j,r,Temps,simul)
$VarEq_{r,t}$	Equivalent Variation	VarEq(r,Temps,simul)

$VEQCH_{i,r,t}$	Consumption for Equivalent Variation	VEQCH(i,r,Temps,simul)
$VEQCHC_{AGI,r,t}$	Quantity AGI for Equivalent Variation	VEQCHC(AGI,r,Temps,simul)
$VEQP_{r,t}$	Price Index definition for AUX for Equivalent Variation	VEQP(r,Temps,simul)
$VEQPCC_{AGI,r,t}$	Index Price for AGI for Equivalent Variation	VEQPCC(AGI,r,Temps,simul)
$WHG_{gender,r,t}$	Rate of return to skilled labor	WHG(Gender,r,Temps,simul)
$WHG\_REC_{gender,REC,t}$	Wages (skilled labor) in the integrated market	WHG_REC(Gender,REC, Temps, simul)
$WK_{i,r,t}$	Rate of return to capital	WK(i,r,Temps,simul)
$\overline{WK}_{r,t}$	Average rate of return of capital	WKBAR(r,temps,simul)
$WK\_REC_{REC,t}$	Capital Return in the integrated market	WK_REC(REC,t,simul)
$WKUNI_{r,t}$	Uniform rate of return of capital	WKUNI(r,Temps,simul)
$WLG\_REC_{gender,REC,t}$	Wages (unskilled labor) in the integrated market	WLG_REC(Gender,REC, Temps, simul)
$WLGt_{Ltype,gender,r,t}$	Rate of return to unskilled labor	WLGt(Ltype,Gender,r,Temps,simul)
$WorldTr_{j,t}$	World supply of international transportation	WorldTr(j,Temps,simul)
$WRN_{j,r,t}$	Rate of return to natural resources	WRN(j,r,Temps,simul)
$WTE_{j,r,t}$	Rate of return to land	WTE(j,r,Temps,simul)
$WTEZ_{mgmentld,i,AEZ,r,t}$	Rate of return to land	WTEZ(ManagementLand,j,AEZ,r,Temps,simul)
$\overline{WTE}_{mgmentld,AEZ,r,t}$	Aggregate price of land	WTEbar(ManagementLand,AEZ,r,Temps,simul)
$Y_{j,r,t}$	Total output of sector j	Y(j,r,Temps,simul)
$Yield_{i,r,t}$	Yield variable	Yield(i,r,temps,simul)

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