



Centro de Estudos de  
Economia Aplicada do Atlântico

## WORKING PAPER SERIES

**CEEApIA WP No. 02/2009**

### **Azormod Dynamic General Equilibrium Model for Azores**

**Mário Fortuna  
Ali Bayar  
Cristina Mohora  
Masudi Opese  
Suat Sisik**

**March 2009**

# **Azormod Dynamic General Equilibrium Model for Azores**

**Mário Fortuna**

Universidade dos Açores (DEG)  
e CEEApIA

**Ali Bayar**

Universite Libre de Bruxelles  
Departement D'Economie Appliquee  
EcoMod

**Cristina Mohora**

Universite Libre de Bruxelles  
Departement D'Economie Appliquee  
EcoMod

**Masudi Opese**

Universite Libre de Bruxelles  
Departement D'Economie Appliquee  
EcoMod

**Suat Sisik**

Universite Libre de Bruxelles  
Departement D'Economie Appliquee  
EcoMod

Working Paper n.º 02/2009  
Março de 2009

## **RESUMO/ABSTRACT**

### **Azormod Dynamic General Equilibrium Model for Azores**

The main objective of this paper is to present a multi-sectoral, multi-regional dynamic modelling platform of the Azores economy integrated within the European and global context. The platform will have the highest capabilities of analysis and forecasting in Azores for problems related to structural sectoral and regional issues, agriculture, labour markets, public finance, trade, EU funds, regional development, environment, and energy. The modelling platform is intended to act as an analytical and quantitative support for policy-making.

Mário Fortuna  
Departamento de Economia e Gestão  
Universidade dos Açores  
Rua da Mãe de Deus, 58  
9501-801 Ponta Delgada

Ali Bayar  
Universite Libre de Bruxelles  
Departement D'Economie Appliquee  
Avenue Paul Heger 2  
B-1000 Bruxelles

Cristina Mohora  
Universite Libre de Bruxelles  
Departement D'Economie Appliquee  
Avenue Paul Heger 2  
B-1000 Bruxelles

Masudi Opese  
Universite Libre de Bruxelles  
Departement D'Economie Appliquee  
Avenue Paul Heger 2  
B-1000 Bruxelles

Suat Sisik  
Universite Libre de Bruxelles  
Departement D'Economie Appliquee  
Avenue Paul Heger 2  
B-1000 Bruxelles

# **AZORMOD DYNAMIC GENERAL EQUILIBRIUM MODEL FOR AZORES**

**Mário Fortuna  
Ali Bayar  
Cristina Mohora  
Masudi Opese  
Suat Sisik**

## **Abstract**

The main objective of this paper is to present a multi-sectoral, multi-regional dynamic modelling platform of the Azores economy integrated within the European and global context. The platform will have the highest capabilities of analysis and forecasting in Azores for problems related to structural sectoral and regional issues, agriculture, labour markets, public finance, trade, EU funds, regional development, environment, and energy. The modelling platform is intended to act as an analytical and quantitative support for policy-making.

## 1 Introduction

The main objective of this paper is to present a multi-sectoral, multi-regional dynamic modelling platform of the Azores economy integrated within the European and global context. The platform will have the highest capabilities of analysis and forecasting in Azores for problems related to structural sectoral and regional issues, agriculture, labour markets, public finance, trade, EU funds, regional development, environment, and energy. The modelling platform is intended to act as an analytical and quantitative support for policy-making.

The current version of the modelling platform of the Azores economy is represented by a dynamic multi-sectoral computable general equilibrium model (CGE), which incorporates the economic behaviour of six economic agents: firms, households, regional government, Mainland government, European Commission and the external sector.

## 2 Technical overview

The goods-producing sectors, consisting of both public and private enterprises, are disaggregated into 45 branches of activity. Households are divided into six income groups, to analyze the distributional effects of various policy measures. Special attention is paid to the economic links between the regional government, the Mainland government and the European Commission. With regard to the rest of the world the economy is treated as a small open economy with no influence on (given) world market prices. Trade relations are differentiated according to four main trade partners: Mainland, EU, US and the rest of the world. The behaviour of each agent in the model is described in detail below.

The model has been solved by using the general algebraic modelling system GAMS (Rosenthal, 2006).

The following conventions are adopted for the presentation of the model. Variable names are given in capital letters, small letters denote parameters calibrated from the database (SAM) and elasticity parameters. The subscript  $s$  stands for one of the production activities (45 branches of activity). The subscript  $c$  stands for one of the commodities (45 types of commodities). The subscript  $qu$  stands for one of the households' income groups (6 households' income groups). The subscript  $ctm$  stands for one of the trade and transport services (7 types of trade and transport services), while  $nctm$  stands for all the other commodities except trade and transport services (38 types of commodities).

### 2.1 Firms

CGE models do not take into account the behaviour of individual firms, but of groups of similar ones aggregated into branches. A presentation of the production sectors considered in AzorMod is provided in Table 1.

The usual assumption for such a model is that producers operate in perfectly competitive markets and maximize profits (or minimize costs for each level of output) to determine the optimal levels of inputs and output. Furthermore, production prices

equal average and marginal costs, a condition implied by profit maximization for a constant returns to scale technology.

The level of production for each branch of activity is determined from a nested production structure (see Figure 1). In the first stage, producers are assumed to choose between intermediate inputs and value-added according to a Leontief production function. In the second stage, the optimal mix between capital and labour is given by another optimization process, where substitution possibilities between capital and labour are represented by a constant elasticity of substitution (CES) function. Firms' costs related to corporate income tax and social security contributions are also taken into account in the optimization process.

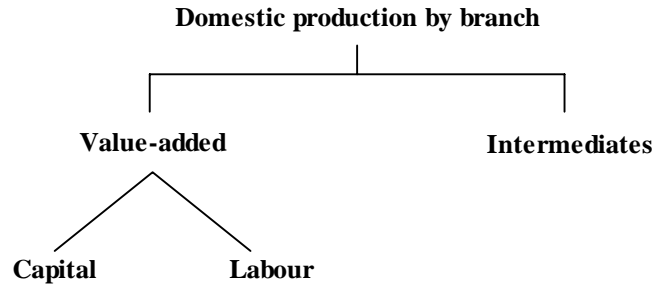


Figure 1. The nested Leontief and CES production technology for the domestic production by branch of activity

Value-added ( $KL_s$ ) is related to domestic production by branch  $s$  ( $XD_s$ ) through a Leontief production function, which assumes an optimal allocation of inputs:

$$KL_s = aKL_s \cdot XD_s \quad (1)$$

where  $aKL_s$  is the well-known fixed coefficient relating value-added to domestic production. Similarly, total intermediate inputs used by industry  $s$  ( $IO_s$ ) are derived as:

$$IO_s = \sum_c io_{c,s} \cdot XD_s \quad (2)$$

where  $io_{c,s}$  are the technical coefficients. Thus, domestic production valued at basic prices net of taxes ( $tp_s$ ) but including direct subsidies ( $tsp_s$ ) on production from the regional

government and direct subsidies on production from the European Agricultural Guidance and Guarantee Fund (EAGGF) ( $tspuea_s$ ), from the Financial Instrument for Fisheries Guidance (FIFG) ( $tspuafi_s$ ), from the European Regional Development Fund (ERDF) ( $tspuer_s$ ), from the European Social Fund (ESF) ( $tspues_s$ ) and from US ( $tspusa_s$ ), is given by the sum of value-added ( $KL_s$ ) for branch  $s$  valued at basic prices ( $PKL_s$ ) and intermediate commodities used by sector  $s$  valued at the price of the commodities ( $P_c$ ), less subsidies on intermediate consumption ( $tsic_{c,s}$ ) but including the trade and transport margins ( $\sum_{ctm} tcictm_{ctm,c,s} \cdot P_{ctm}$ ) and value-added taxes ( $vatic_{c,s}$ ) on intermediate consumption:

*Table 1: Activity and commodity disaggregation in AzorMod*

---

1	Agriculture, hunting and forestry, logging
2	Fishing
3	Mining and quarrying
4	Production of meat and meat products
5	Processing of fish and fish products
6	Manufacture of dairy products
7	Prepared animal feeds
8	Beverages & tobacco products
9	Fruits, vegetables, animal oils, grain mill, starches
10	Textiles and leather
11	Wood and products of wood and cork
12	Pulp, paper products; publishing and printing
13	Coke, refined petroleum products and nuclear fuel
14	Chemicals and chemical products
15	Rubber and plastic products
16	Other non-metallic mineral products
17	Basic metals and fabricated metal products
18	Machinery and equipment n.e.c.
19	Electrical and optical equipment
20	Transport equipment
21	Manufacturing n.e.c.
22	Electricity, gas, steam and hot water supply
23	Collection, purification and distribution of water
24	Construction
25	Sale, maintenance, repair of motor vehicles and motorcycles
26	Wholesale trade and commission trade, except of motor vehicles and motorcycles
27	Retail trade, except of motor vehicles and motorcycles
28	Hotels and restaurants
29	Land transport; transport via pipelines
30	Water transport
31	Air transport
32	Supporting transport activities; activities of travel agencies
33	Post and telecommunications
34	Financial intermediation, excluding insurance and pension funding
35	Insurance and pension funding, except compulsory social security
36	Activities auxiliary to financial intermediation
37	Real estate activities
38	Renting of machinery and equipment without operator
39	Computer and related activities; research and development
40	Other business activities
41	Public administration and defence; compulsory social security
42	Education
43	Health and social work
44	Other community, social and personal service activities
45	Activities of households as employers of domestic staff

---

$$\begin{aligned}
& PD_s \cdot (1 - tp_s + tsp_s + tspeuea_s \cdot MUtspeu + tspeufi_s \cdot MUtspeu + tspeuer_s \cdot MUtspeu + \\
& tspeues_s \cdot MUtspeu + tspusa_s) \cdot XD_s = PKL_s \cdot KL_s + \\
& \sum_c \{ io_{c,s} \cdot XD_s \cdot [(1 - tsic_{c,s}) \cdot P_c + \sum_{ctm} tcictm_{ctm,c,s} \cdot P_{ctm}] \cdot (1 + vatic_{c,s}) \}
\end{aligned} \tag{3}$$

Parameter  $MUtspeu$  insures the consistency between the total EU funds provided as subsidies on production and the EU subsidies on production by branch of activity.

The trade and transport margins are valued at the price ( $P_{ctm}$ ) of the corresponding service (trade services or transport services), while  $tcictm_{ctm,c,s}$  represents the trade and transport services  $ctm$  per unit of intermediate consumption of commodity  $c$  by branch  $s$ .

Value-added is a CES aggregation of capital ( $KSK_s$ ) and labour ( $LSK_s$ ):

$$KL_s = aF_s \cdot [\gamma FK_s \cdot KSK_s^{-\rho F_s} + \gamma FL_s \cdot LSK_s^{-\rho F_s}]^{-1/\rho F_s} \tag{4}$$

Minimizing the costs function:

$$\begin{aligned}
Cost_s(KSK_s, LSK_s) = & [PK_s \cdot (1 + tk_s) + d_s \cdot PI] \cdot KSK_s + [PL \cdot (1 + premLSK_s) \cdot \\
& (1 + tl_s / (1 - tl_s))] \cdot LSK_s
\end{aligned} \tag{5}$$

subject to (4) yields the demand equations for capital and labour:

$$KSK_s = KL_s \cdot \{ PKL_s / [PK_s \cdot (1 + tk_s) + d_s \cdot PI] \}^{\sigma F_s} \cdot \gamma FK_s^{\sigma F_s} \cdot aF_s^{(\sigma F_s - 1)} \tag{6}$$

$$LSK_s = KL_s \cdot \{ PKL_s / [PL \cdot (1 + premLSK_s) \cdot (1 + tl_s / (1 - tl_s))] \}^{\sigma F_s} \cdot \gamma FL_s^{\sigma F_s} \cdot aF_s^{(\sigma F_s - 1)} \tag{7}$$

and the associated zero profit condition:

$$PKL_s \cdot KL_s = PK_s \cdot (1 + tk_s) \cdot KSK_s + PL \cdot (1 + premLSK_s) \cdot (1 + tl_s / (1 - tl_s)) \cdot LSK_s + DEP_s \cdot PI \tag{8}$$

where  $PL$  is the national average wage and  $premsLK_s$  is the wage differential of branch  $s$  with respect to the average wage  $PL$ ,  $tl_s$  is the social security contributions rate for industry  $s$ ,  $PK_s$  is the return to capital in branch  $s$ ,  $tk_s$  is the corporate income tax rate for branch  $s$ , and  $d_s$  is the depreciation rate in industry  $s$ . The depreciation ( $DEP_s$ ) related to the private and public capital stock is valued at the investment price index ( $PI$ ). The elasticity of substitution between capital and labour is given by  $\sigma F_s$ , where  $\sigma F_s = 1 / (1 + \rho F_s)$ , and  $\gamma FK_s$  and  $\gamma FL_s$  represent the distribution parameters corresponding to capital and labour.

Capital is industry specific, introducing rigidities in the capital market. The inter-sectoral wage differential is a parameter derived as the ratio between the wage by branch and the national average wage (Dervis, De Melo and Robinson, 1982). Holding the inter-sectoral wage differentials constant in counterfactual policy simulations introduces rigidities in the labour market.

Each branch of activity in AzorMod produces several types of goods and services. The optimal allocation of domestic production between the different types of commodities is given by a Leontief function:

$$XDDE_c = \sum_s io_{C,s,c} \cdot XD_s \tag{9}$$

where  $XDD E_c$  represents the domestic production of commodity  $c$  by different branches, supplied on the home and foreign markets,  $XD_s$  is the domestic production of branch  $s$ , and  $ioC_{s,c}$  is a fixed coefficient expressing the volume of production of commodity  $c$  by the industry  $s$  per unit of production of industry  $s$ .

The corresponding zero profit condition is given by:

$$PD_s = \sum_c ioC_{s,c} \cdot PDDE_c \quad (10)$$

where  $PDDE_c$  is the domestic price of commodity  $c$  supplied on the home and foreign markets and  $PD_s$  is the price index corresponding to domestic production by branch  $s$ .

Treated at an aggregate level, firms' savings are given by a share of the net operating surplus.

## 2.2 Households

Households are split into six income groups, the first group being the poorest one. The representative household in each income group receives a part of the capital income (net operating surplus), a part of the labour income, unemployment benefits from the Mainland government and other net transfers from the regional and Mainland governments. The representative household in each income group pays income taxes and saves a share of the net income. Household savings by income group  $qu$  ( $SH_{qu}$ ), are given by:

$$SH_{qu} = MPS_{qu} \cdot (1 - ty_{qu}) \cdot YH_{qu} \quad (11)$$

where  $YH_{qu}$  is the household income,  $ty_{qu}$  is the personal income tax rate and  $MPS_{qu}$  the household propensity to save. Household propensity to save reacts to changes in the after-tax average return to capital, according to:

$$MPS_{qu} = MPSZ_{qu} \cdot \{[(1 - ty_{qu}) \cdot PKavr] / [(1 - tyz_{qu}) \cdot PKavrZ]\}^{elas_{qu}} \quad (12)$$

where  $MPSZ_{qu}$  is the benchmark level of the propensity to save,  $PKavr$  is the real average return to capital received by the household,  $PKavrZ$  is the benchmark level of  $PKavr$ ,  $tyz_{qu}$  is the benchmark level of the personal income tax rate and  $elas_{qu}$  is the elasticity of savings with respect to after-tax rate of return. Subsequently, household budget disposable for consumption ( $CBUD_{qu}$ ) is derived as:

$$CBUD_{qu} = (1 - ty_{qu}) \cdot YH_{qu} - SH_{qu} \quad (13)$$

The disposable budget for consumption is allocated between different goods and services according to a Stone-Geary utility function. Maximizing the utility function:

$$U(C_{c,qu}) = \prod_c (C_{c,qu} - \mu H_{c,qu})^{\alpha H_{c,qu}} \quad (14)$$

subject to the budget constraint:

$$CBUD_{qu} = \sum_c \{ [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + vatc_{c,qu} + tc_{c,qu}) \cdot C_{c,qu} \} \quad (15)$$

with:  $\sum_c \alpha H_{c,qu} = 1$ , yields the demand equations for commodities:

$$\begin{aligned}
& [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatc_{c,qu}) \cdot C_{c,qu} = [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot \\
& (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatc_{c,qu}) \cdot \mu H_{c,qu} + \alpha H_{c,qu} \cdot \{CBUD_{qu} - \sum_{cc} [P_{cc} + \sum_{ctm} tchtm_{ctm,cc,qu} \cdot P_{ctm}] \cdot \\
& (1 + texc_{cc,qu}) \cdot (1 + tc_{cc,qu} + vatc_{cc,qu}) \cdot \mu H_{cc,qu} \}
\end{aligned} \quad (16)$$

Consumption of commodity  $c$  by income group  $qu$  ( $C_{c,qu}$ ) is valued at purchaser's prices, which include trade and transport margins ( $\sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}$ ), excise duties ( $texc_{c,qu}$ ), value-added taxes ( $vatc_{c,qu}$ ) and other taxes on consumption ( $tc_{c,qu}$ ), where  $P_c$  is the price of commodity  $c$  net of taxes. The trade and transport margins on private consumption are valued at the prices corresponding to the trade and transport services ( $P_{ctm}$ ), where  $tchtm_{ctm,c,qu}$  represents the quantity of trade and transport services  $ctm$  per unit of commodity  $c$  consumed by the income group  $qu$ .

In the allocation process, the consumer first decides on the minimum (subsistence) level of consumption of commodity  $c$  ( $\mu H_{c,qu}$ ). Then, the marginal income is allocated between different types of commodities according to the marginal budget shares ( $\alpha H_{c,qu}$ ). A schematic representation of households' decisions, by income group, is given in Figure 2.

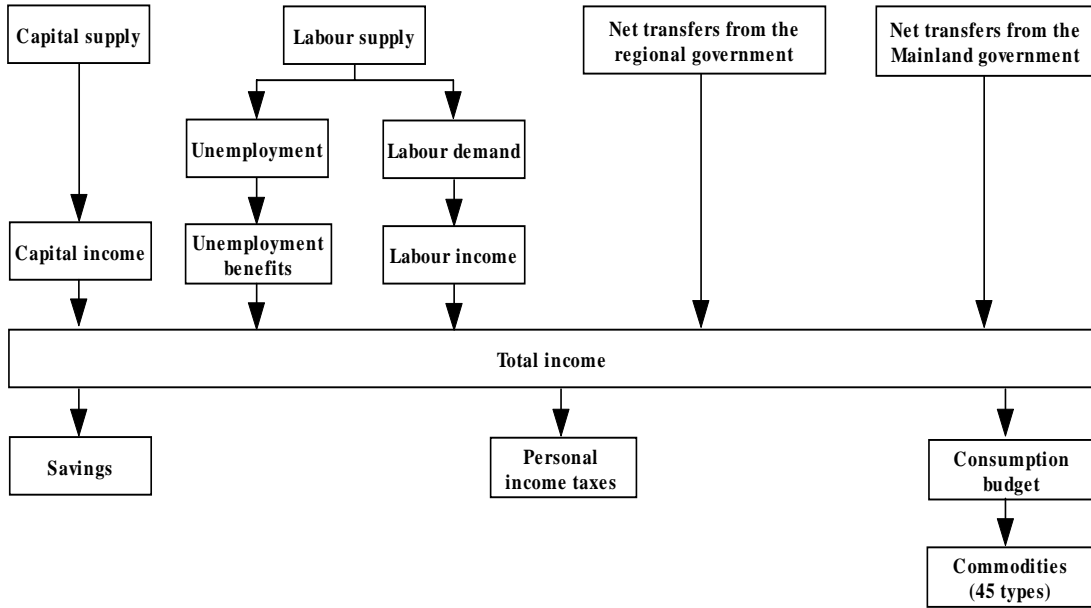


Figure 2. Decision structure of the representative household by income group

Household welfare gains/losses are valued using the equivalent variation in income ( $EV_{qu}$ ), which is based on the concept of a money metric indirect utility function (Varian, 1992).

$$\begin{aligned}
EV_{qu} = & \prod_c \{ [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vatcz_{c,qu}) \} / \\
& \alpha H_{c,qu}^{\alpha H_{c,qu}} \cdot (VU_{qu} - VUI_{qu})
\end{aligned} \quad (17)$$

The indirect utility function ( $VU_{qu}$ ) corresponding to the Linear Expenditures System (LES) in the counter-factual (policy scenario) equilibrium is defined as:

$$\begin{aligned}
VU_{qu} = & \{CBUD_{qu} - \sum_c [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1+texc_{c,qu}) \cdot (1+tc_{c,qu} + vatic_{c,qu}) \cdot \\
& \mu H_{c,qu} \} \cdot \prod_c \{ \alpha H_{c,qu} / \{ [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1+texc_{c,qu}) \cdot (1+tc_{c,qu} + \\
& vatic_{c,qu}) \} \}^{\alpha H_{c,qu}}
\end{aligned} \tag{18}$$

and the indirect utility function ( $VUI_{qu}$ ) in the benchmark equilibrium is given by:

$$\begin{aligned}
VUI_{qu} = & \{CBUDZ_{qu} - \sum_c [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1+texcz_{c,qu}) \cdot (1+tcz_{c,qu} + vatcz_{c,qu}) \cdot \\
& \mu H_{c,qu} \} \cdot \prod_c \{ \alpha H_{c,qu} / \{ [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1+texcz_{c,qu}) \cdot (1+tcz_{c,qu} + \\
& vatcz_{c,qu}) \} \}^{\alpha H_{c,qu}}
\end{aligned} \tag{19}$$

where  $CBUDZ_{qu}$  is the benchmark level of the disposable budget for consumption,  $PZ_c$  is the benchmark level of the price of commodity  $c$  net of taxes,  $tchtmz_{ctm,c,qu}$  is the benchmark level of the trade and transport margin rate, and  $texcz_{c,qu}$ ,  $vatcz_{c,qu}$  and  $tcz_{c,qu}$  are the benchmark rates corresponding to excise duties, value-added taxes, and other taxes on consumption, respectively.

Equivalent variation measures the income needed to make the household as well off as she is in the new counter-factual equilibrium (policy scenario) evaluated at benchmark prices. Thus, the equivalent variation is positive for welfare gains from the policy scenario and negative for losses.

### 2.3 Regional government

Regional government collects all the taxes, such as: taxes on income and wealth ( $TRPROP$ ) and taxes on products and on production ( $TRPROD$ ) and receives transfers from the Mainland government, EU funds and transfers from the external sector ( $TRANSR$ ) (see Figure 3):

$$GREV = TRPROP + TRPROD + TRANSR \tag{20}$$

where  $GREV$  stands for the total government revenues.

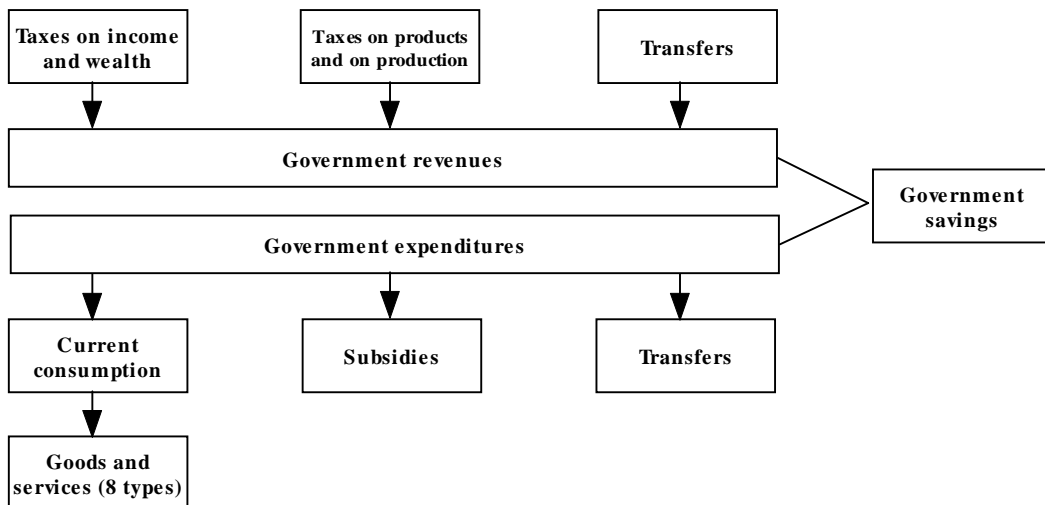


Figure 3. Structure of the regional government budget

The taxes on income and wealth are given by:

$$TRPROP = \sum_{qu} ty_{qu} \cdot YH_{qu} + \sum_s tk_s \cdot KSK_s \cdot PK_s \quad (21)$$

In the derivation of each category of tax revenue the tax rate is applied to the corresponding tax base.

Taxes on products are differentiated in the model according to the category of consumption on which they apply: intermediate consumption, private consumption, and gross capital formation. Taxes on products and on production are provided by:

$$\begin{aligned} TRPROD = & \sum_s tp_s \cdot XD_s \cdot PD_s + \sum_{c,qu} \{ [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot [texc_{c,qu} + (1 + \\ & texc_{c,qu}) \cdot (tc_{c,qu} + vatic_{c,qu})] \cdot C_{c,qu} \} + \sum_c [P_c + \sum_{ctm} tcitm_{ctm,c} \cdot P_{ctm}] \cdot vatic_c \cdot I_c + \\ & \sum_{c,s} [(1 - tsic_{c,s}) \cdot P_c + \sum_{ctm} tcictm_{ctm,c,s} \cdot P_{ctm}] \cdot vatic_{c,s} \cdot io_{c,s} \cdot XD_s + \sum_c (tmus_c \cdot PWMUS_c \cdot \\ & MUS_c \cdot ERUS) + \sum_c (tmrw_c \cdot PWMROW_c \cdot MROW_c \cdot ERROW) \end{aligned} \quad (22)$$

where  $I_c$  represents the investment demand for commodity  $c$ ,  $tcitm_{ctm,c}$  gives the trade and transport margin rate on investment good  $c$ ,  $vatic_c$  gives the value-added tax rate on investment good  $c$ ,  $tmus_c$  represents the tariff rate on commodity  $c$  coming from US,  $MUS_c$  give the imports of commodity  $c$  from US,  $PWMUS_c$  stands for the import price of commodity  $c$  from US expressed in foreign currency and  $ERUS$  is the exchange rate with respect to the US dollar. Tariff rate on commodity  $c$  coming from the rest of the world (ROW) ( $tmrw_c$ ) is applied to the imports of commodity  $c$  from the ROW ( $MROW_c$ ), valued at the import price expressed in foreign currency ( $PWMROW_c$ ), and transformed in domestic currency using the exchange rate  $ERROW$ .

The total transfers received by the regional government ( $TRANSR$ ) are given by transfers from the Mainland government ( $TRGML$ ), transfers from EU as direct subsidies on production ( $TRGEC$ ) and other transfers from EU ( $TRGEU$ ), transfers from US ( $TRGUS$ ) and transfers from the rest of the world ( $TRGW$ ):

$$TRANSR = TRGML \cdot ERML + TRGEU \cdot EREU + TRGEC \cdot EREU + TRGUS \cdot ERUS + TRGW \cdot ERROW \quad (23)$$

where the transfers are expressed in domestic currency using the exchange rate with respect to Mainland ( $ERML$ ), the exchange rate with respect to EU ( $EREU$ ), the exchange rate with respect to US ( $ERUS$ ) and the exchange rate with respect to the rest of the world ( $ERROW$ ).

Regional government expenditures ( $GEXP$ ) comprise the public current consumption ( $CGBUD$ ), total transfers by the government ( $TRANS$ ) and subsidies on products and on production ( $SUBSID$ ):

$$GEXP = CGBUD + TRANS + SUBSID \quad (24)$$

The optimal allocation of the public current consumption between different types of goods and services is given by the maximization of a Cobb-Douglas function:

$$U(CG_c) = \prod_c CG_c^{\alpha CG_c} \quad (25)$$

subject to the budget constraint:

$$CGBUD = \sum_c P_c \cdot CG_c \quad (26)$$

with:  $\sum_c \alpha CG_c = 1$ . The maximization of  $U(CG_c)$  yields the demand equations for public current consumption by type of commodity:

$$P_c \cdot CG_c = \alpha CG_c \cdot CGBUD \quad (27)$$

where  $CG_c$  represents the public demand for commodity  $c$ ,  $P_c$  is the price of commodity  $c$  and  $\alpha CG_c$  gives the Cobb-Douglas preference parameter corresponding to commodity  $c$ .

Total transfers by the regional government include transfers to the households ( $TRHG_{qu}$ ):

$$TRANS = \sum_{qu} TRHG_{qu} \cdot PCINDEX \quad (28)$$

translated into nominal terms by using the Laspeyres consumer price index ( $PCINDEX$ ).

The total subsidies on products and on production are further derived as:

$$SUBSID = \sum_{c,s} tsic_{c,s} \cdot P_c \cdot io_{c,s} \cdot XD_s + \sum_s [(tsp_s + tspeuea_s \cdot MUspeu + tspeufi_s \cdot MUspeu + tspeuer_s \cdot MUspeu + tspeues_s \cdot MUspeu + tspusa_s) \cdot XD_s \cdot PD_s] \quad (29)$$

The EU funds as direct subsidies on production are transferred to the regional government budget which allocates them between different branches of activity.  $MUspeu$  is a scaling parameter which insures the consistency between the total EU funds and the total subsidies on production distributed to different branches of activity:

$$TRGEC \cdot EREU = MUspeu \cdot \sum_s [(tspeuea_s + tspeufi_s + tspeuer_s + tspeues_s) \cdot XD_s \cdot PD_s] \quad (30)$$

The difference between the regional government revenues and the government expenditures yields the government savings ( $SG$ ).

$$SG = GREV - GEXP \quad (31)$$

## 2.4 Mainland government

Mainland government collects all the social security contributions, provides unemployment benefits and makes transfers to the households ( $TRHML_{qu}$ ) and to the regional government ( $TRGML$ ).

Social security contributions are derived by applying the social contributions rate ( $tl_s$ ) to gross wages. Unemployment benefits received by each household income group are determined by the combination of the replacement rate ( $trep$ ), the national average wage ( $PL$ ), the total number of unemployed ( $UNEMP$ ), and the share of unemployed subject to unemployment benefits in each household income group ( $shUNEMPB_{qu}$ ).

The net transfers by the mainland government to Azores ( $SGML$ ), are provided by:

$$SGML = \sum_s [tl_s / (1 - tl_s) \cdot LSK_s \cdot PL \cdot (1 + premLSK_s) / ERML] - \sum_{qu} TRHML_{qu} - \sum_{qu} (shUNEMPB_{qu} \cdot trep \cdot PL \cdot UNEMP / ERML) - TRGML \quad (32)$$

## 2.5 European Commission

European Commission provides EU funds as direct subsidies to the production sectors (*TRGEC*) and other EU funds (*TRGEU*) to the regional government. The net transfers by the European Commission to Azores (*SGEC*) are given by:

$$SGEC = -TRGEC - TRGEU \quad (33)$$

## 2.6 Foreign trade

The specification of the foreign trade is based on the small-country assumption, which means that the country is a price taker in both its import and its export markets. Four different trade partners are distinguished in the model: Mainland, EU, US and the rest of the world.

On the import side, imperfect substitution is assumed between domestically produced and imported goods, according to the Armington function (see Figure 4). Thus, domestic consumers use composite goods ( $X_c$ ) of imported and domestically produced goods, according to a CES function:

$$X_c = aA_c \cdot (\gamma A1_c \cdot MML_c^{-\rho A_c} + \gamma A2_c \cdot MEU_c^{-\rho A_c} + \gamma A3_c \cdot MUS_c^{-\rho A_c} + \gamma A4_c \cdot MROW_c^{-\rho A_c} + \gamma A5_c \cdot XDD_c^{-\rho A_c})^{-1/\rho A_c} \quad (34)$$

Minimizing the cost function:

$$Cost_c(MML_c, MEU_c, MUS_c, MROW_c, XDD_c) = PMML_c \cdot MML_c + PMEU_c \cdot MEU_c + PMUS_c \cdot MUS_c + PMROW_c \cdot MROW_c + PDD_c \cdot XDD_c \quad (35)$$

subject to (34) provides the demand for imports from Mainland ( $MML_c$ ), the demand for imports from EU ( $MEU_c$ ), the demand for imports from US ( $MUS_c$ ), the demand for imports from ROW ( $MROW_c$ ), and the demand for domestically produced goods ( $XDD_c$ ):

$$MML_c = X_c \cdot (P_c / PMML_c)^{\sigma A_c} \cdot \gamma A1_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (36)$$

$$MEU_c = X_c \cdot (P_c / PMEU_c)^{\sigma A_c} \cdot \gamma A2_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (37)$$

$$MUS_c = X_c \cdot (P_c / PMUS_c)^{\sigma A_c} \cdot \gamma A3_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (38)$$

$$MROW_c = X_c \cdot (P_c / PMROW_c)^{\sigma A_c} \cdot \gamma A4_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (39)$$

$$XDD_c = X_c \cdot (P_c / PDD_c)^{\sigma A_c} \cdot \gamma A5_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (40)$$

and the corresponding zero profit condition:

$$P_c \cdot X_c = PMML_c \cdot MML_c + PMEU_c \cdot MEU_c + PMUS_c \cdot MUS_c + PMROW_c \cdot MROW_c + PDD_c \cdot XDD_c \quad (41)$$

where  $P_c$  is the price index of the composite good  $c$  incorporating the imported and domestically produced goods supplied on the domestic market,  $PMML_c$  represents the domestic price of imports from Mainland,  $PMEU_c$  is the domestic price of imports from EU,  $PMUS_c$  gives the domestic price of imports from US (including tariffs),  $PMROW_c$  represents the domestic price of imports from ROW (including tariffs) and  $PDD_c$  is the price of good  $c$  from the domestic producers.  $aA_c$  represents the efficiency parameter while  $\gamma A1_c$ ,  $\gamma A2_c$ ,  $\gamma A3_c$ ,  $\gamma A4_c$  and  $\gamma A5_c$  are the distribution parameters corresponding to imports from Mainland, imports from EU, imports from US, imports from ROW and domestic demand for the domestically produced goods, respectively. The elasticity of substitution between imports and domestically produced goods ( $\sigma A_c$ ) is given by  $1/(1 + \rho A_c)$ .

In a similar fashion, the differentiation between the exported goods by the domestic producers to Mainland ( $EML_c$ ), to EU ( $EEU_c$ ), to US ( $EUS_c$ ) and to ROW ( $EROW_c$ ) and the domestic goods supplied on the domestic market ( $XDD_c$ ) is captured through a constant elasticity of transformation (CET) function:

$$XDDE_c = aT_c \cdot (\gamma T1_c \cdot EML_c^{-\rho T_c} + \gamma T2_c \cdot EEU_c^{-\rho T_c} + \gamma T3_c \cdot EUS_c^{-\rho T_c} + \gamma T4_c \cdot EROW_c^{-\rho T_c} + \gamma T5_c \cdot XDD_c^{-\rho T_c})^{-1/\rho T_c} \quad (42)$$

where  $XDDE_c$  is the domestic production of commodity  $c$  by different branches, supplied on the home and foreign markets,  $aT_c$  is the efficiency parameter,  $\gamma T1_c$ ,  $\gamma T2_c$ ,  $\gamma T3_c$ ,  $\gamma T4_c$  and  $\gamma T5_c$  are the distribution parameters corresponding to  $EML_c$ ,  $EEU_c$ ,  $EUS_c$ ,  $EROW_c$  and  $XDD_c$ , respectively, and the elasticity of transformation ( $\sigma T_c$ ) between domestically produced goods supplied on the domestic market and the exports by the domestic producers is given by  $1/(1 + \rho T_c)$ .

By maximizing the revenue:

$$Revenue_c(EML_c, EEU_c, EUS_c, EROW_c, XDD_c) = PEML_c \cdot EML_c + PEEU_c \cdot EEU_c + PEUS_c \cdot EUS_c + PEROW_c \cdot EROW_c + PDD_c \cdot XDD_c \quad (43)$$

subject to (42) we derive the supply of exports by the domestic producers to Mainland, to EU, to US and to ROW and the supply by the domestic producers to the domestic market:

$$EML_c = XDDE_c \cdot (PDDE_c/PEML_c)^{\sigma T_c} \cdot \gamma T1_c^{\sigma T_c} \cdot aT_c^{(\sigma T_c-1)} \quad (44)$$

$$EEU_c = XDDE_c \cdot (PDDE_c/PEEU_c)^{\sigma T_c} \cdot \gamma T2_c^{\sigma T_c} \cdot aT_c^{(\sigma T_c-1)} \quad (45)$$

$$EUS_c = XDDE_c \cdot (PDDE_c/PEUS_c)^{\sigma T_c} \cdot \gamma T3_c^{\sigma T_c} \cdot aT_c^{(\sigma T_c-1)} \quad (46)$$

$$EROW_c = XDDE_c \cdot (PDDE_c/PEROW_c)^{\sigma T_c} \cdot \gamma T4_c^{\sigma T_c} \cdot aT_c^{(\sigma T_c-1)} \quad (47)$$

$$XDD_c = XDDE_c \cdot (PDDE_c/PDD_c)^{\sigma T_c} \cdot \gamma T5_c^{\sigma T_c} \cdot aT_c^{(\sigma T_c-1)} \quad (48)$$

and the corresponding zero profit condition:

$$PDDE_c \cdot XDDE_c = PDD_c \cdot XDD_c + PEML_c \cdot EML_c + PEEU_c \cdot EEU_c + PEUS_c \cdot EUS_c + PEROW_c \cdot EROW_c \quad (49)$$

where  $PDDE_c$  is the price index corresponding to  $XDDE_c$ ,  $PEML_c$  represents the domestic price of exports to Mainland received by the domestic producers,  $PEEU_c$  gives the domestic price of exports to EU received by the domestic producers,  $PEUS_c$  is the

domestic price of exports to US and  $PEROW_c$  represents the domestic price of exports to ROW.

In addition, export demand functions are introduced in the model (see Figure 4):

$$EDML_c = EDIML_c \cdot (PWEML_c \cdot ERML/PEML_c)^{elasE_c} \quad (50)$$

$$EDEU_c = EDIEU_c \cdot (PWEEU_c \cdot EREU/PEEU_c)^{elasE_c} \quad (51)$$

$$EDUS_c = EDIUS_c \cdot (PWEUS_c \cdot ERUS/PEUS_c)^{elasE_c} \quad (52)$$

$$EDROW_c = EDIROW_c \cdot (PWEROW_c \cdot ERROW/PEROW_c)^{elasE_c} \quad (53)$$

such that the export demand for domestically produced goods by the external sector, depends on the benchmark level of the export demand by the foreign sector, the relative price change and the price elasticity of export demand ( $elasE_c$ ).  $EDML_c$ ,  $EDEU_c$ ,  $EDUS_c$  and  $EDROW_c$  represent the export demand for domestically produced goods by the Mainland, EU, US and ROW, respectively, while their benchmark levels are provided by  $EDIML_c$ ,  $EDIEU_c$ ,  $EDIUS_c$  and  $EDIROW_c$ , respectively.  $PWEML_c$  represents the price of exports of commodity  $c$  to Mainland, expressed in foreign currency,  $PWEEU_c$  gives the price of exports to EU in foreign currency,  $PWEUS_c$  is the price of exports to US in foreign currency and  $PWEROW_c$  provides the price of exports to ROW in foreign currency.

The market clearing equations for exports:

$$EML_c = EDML_c \quad (54)$$

$$EEU_c = EDEU_c \quad (55)$$

$$EUS_c = EDUS_c \quad (56)$$

$$EROW_c = EDROW_c \quad (57)$$

determine the domestic price of exports received by the domestic producers.

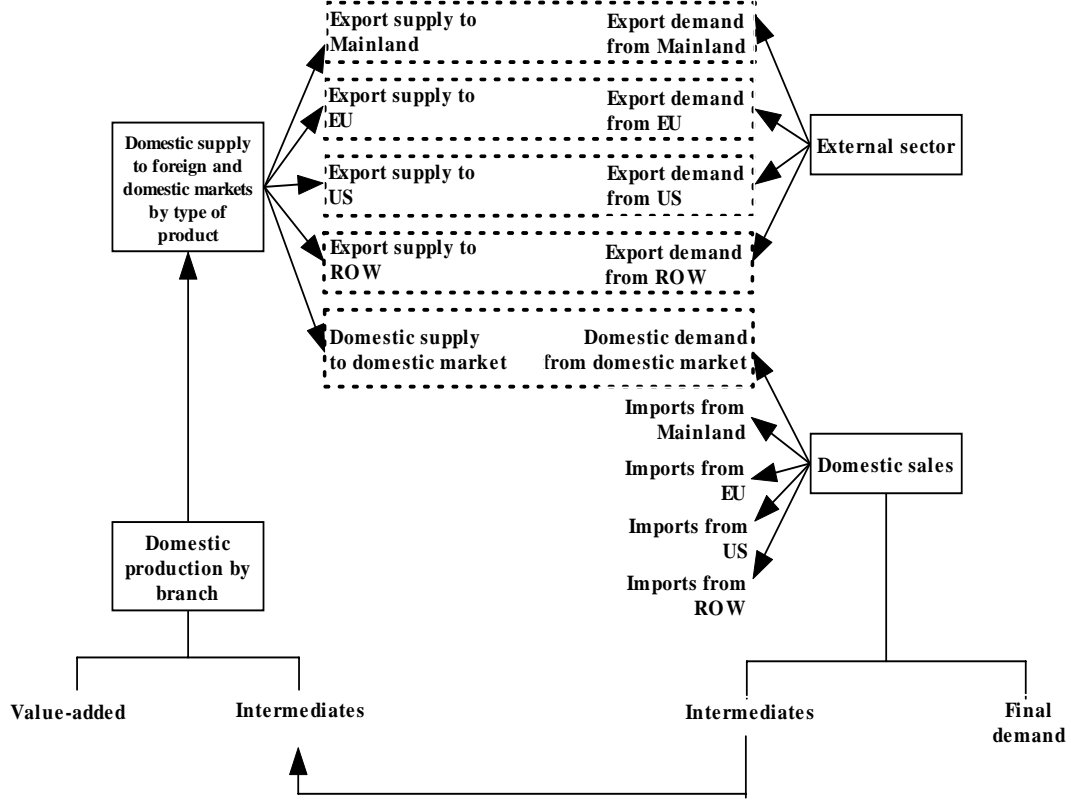


Figure 4. Foreign trade specification

Balance of payments, expressed in foreign currency, takes into account all the trade and capital flows and is differentiated according to each trade partner:

$$SML = \sum_c (MML_c \cdot PWMML_c - EML_c \cdot PEML_c / ERML) + SGML \quad (58)$$

$$SEU = \sum_c (MEU_c \cdot PWMEU_c - EEU_c \cdot PEEU_c / EREU) + SGEC \quad (59)$$

$$SUS = \sum_c (MUS_c \cdot PWMUS_c - EUS_c \cdot PEUS_c / ERUS) - TRGUS \quad (60)$$

$$SROW = \sum_c (MROW_c \cdot PWMROW_c - EROW_c \cdot PEROW_c / ERROW) - TRGW \quad (61)$$

where  $SML$  reflects the surplus/deficit of the current account with respect to Mainland,  $SEU$  is the surplus/deficit of the current account with respect to EU,  $SUS$  provides the balance of the current account with respect to US and  $SROW$  gives the balance of the current account with respect to ROW.

## 2.7 Investment demand

Total savings ( $S$ ) used to buy investment goods are given by:

$$S = \sum_{qu} SH_{qu} + SF + SG \cdot GDPDEF + SML \cdot ERML + SEU \cdot EREU + SUS \cdot ERUS + SROW \cdot ERROW + \sum_s DEP_s \cdot PI \quad (62)$$

where  $SH_{qu}$  represents the households savings by income group,  $SF$  stands for firms savings,  $SG$  gives the regional government savings, expressed in nominal terms using the GDP deflator ( $GDPDEF$ ), and  $\sum_s DEP_s \cdot PI$  is the depreciation related to the private and public capital stock. The balance of the current accounts corresponding to Mainland, EU, US and ROW are expressed in domestic currency using the exchange rates with respect to Mainland ( $ERML$ ), to EU ( $EREU$ ), to US ( $ERUS$ ) and to the rest of the world ( $ERROW$ ).

The depreciation related to the private and public capital stock is valued at the price index of investments ( $PI$ ) and is derived as:

$$DEP_s = d_s \cdot KSK_s \quad (63)$$

where  $d_s$  is the depreciation rate and  $KSK_s$  gives the capital stock of industry  $s$ .

Total investments in real terms ( $ITT$ ) are given by:

$$PI \cdot ITT = S - \sum_c SV_c \cdot P_c \quad (64)$$

where  $SV_c$  stands for the inventories of commodity  $c$ .

The optimal allocation of total investments ( $ITT$ ) between different types of investment commodities ( $I_c$ ) is given by the Leontief function:

$$I_c = ioI_c \cdot ITT \quad (65)$$

where  $ioI_c$  is a parameter that provides the composition of total investments in terms of investment goods.

The composite price (unit cost) of investments ( $PI$ ) is defined as the weighted average of the price of investment goods:

$$PI = \sum_c \{ (1 + vati_c) \cdot [P_c + \sum_{ctm} tcitm_{ctm,c} \cdot P_{ctm}] \cdot ioI_c \} \quad (66)$$

where  $P_c$  stands for the price of (investment) commodity  $c$ ,  $vati_c$  is the value-added tax rate on investment goods  $c$  and  $tcitm_{ctm,c}$  is the trade and transport margin rate on investment good  $c$ .

## 2.8 Price equations

A common assumption for CGE models, which has also been adopted here, is that the economy is initially in equilibrium with the quantities normalized in such a way that prices of commodities equal unity. Due to the homogeneity of degree zero in prices, the model only determines the relative prices. Therefore, a particular price is selected to provide the numeraire against which all relative prices in the model will be measured. We choose the GDP deflator ( $GDPDEF$ ) as the numeraire.

Different prices are defined for all the branches, exports and imports. As already explained, trade and transport margins are paid on all categories of demand in AzorMod except the government consumption (on intermediate consumption, on private consumption and on investment goods).

The domestic price of imports from Mainland ( $PMML_c$ ) is determined by the price of imports from Mainland expressed in foreign currency ( $PWMML_c$ ) and the exchange rate ( $ERML$ ):

$$PMML_c = PWMML_c \cdot ERML \quad (67)$$

Similarly, the domestic price of imports from EU ( $PMEU_c$ ) is given by the price of imports from EU expressed in foreign currency ( $PWMEU_c$ ) and the corresponding exchange rate ( $EREU$ ):

$$PMEU_c = PWMEU_c \cdot EREU \quad (68)$$

The domestic price of imports from US ( $PMUS_c$ ) and from ROW ( $PMROW_c$ ), further include the tariff rate on commodity  $c$  for imports from US ( $tmus_c$ ) and the tariff rate on imports from ROW ( $tmrw_c$ ):

$$PMUS_c = PWMUS_c \cdot ERUS \cdot (1 + tmus_c) \quad (69)$$

$$PMROW_c = PWMROW_c \cdot ERROW \cdot (1 + tmrw_c) \quad (70)$$

where  $PWMUS_c$  and  $PWMROW_c$  stand for the world price of imports from US and from ROW, respectively, and  $ERUS$  and  $ERROW$  provide the exchange rates with respect to US and ROW, respectively.

The consumer price index ( $PCINDEX$ ) used in the model is defined as:

$$PCINDEX = \frac{\sum_{c,qu} \{ [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatc_{c,qu}) \cdot CZ_{c,qu} \}}{\sum_{c,qu} \{ [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vatcz_{c,qu}) \cdot CZ_{c,qu} \}} \quad (71)$$

where  $P_c$  is the price index of commodity  $c$  net of taxes and  $PZ_c$  gives its benchmark level,  $tchtm_{ctm,c,qu}$  represents the trade and transport margin rate on private consumption and  $tchtmz_{ctm,c,qu}$  is its benchmark level,  $texc_{c,qu}$  gives the excise duties rate and  $texc_{c,qu}$  its benchmark level,  $vatc_{c,qu}$  provides the value-added tax rate and  $vatcz_{c,qu}$  its benchmark level and  $tc_{c,qu}$  gives the tax rate corresponding to other taxes on private consumption, while  $tcz_{c,qu}$  is its benchmark level. Finally,  $CZ_{c,qu}$  accounts for the benchmark level of private consumption of commodity  $c$  by income group  $qu$ .

Consumer prices ( $PCT_{c,qu}$ ) are further defined as:

$$PCT_{c,qu} = [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatc_{c,qu}) \quad (72)$$

## 2.9 Labour market

The following identity defines the relation between the labour supply, the labour demand, and unemployment:

$$\sum_s LSK_s = LSR - UNEMP \quad (73)$$

where  $LSK_s$  stands for the number of employees in industry  $s$ ,  $UNEMP$  represents the number of unemployed and  $LSR$  reflects the active population.

The responsiveness of real wage to the labour market conditions is surprised by a wage curve (Sanz-de-Galdeano & Turunen, 2006):

$$\log(PL/PCINDEX) = elasU \cdot \log(UNRATE) + err \quad (74)$$

where  $PL$  is the nominal average wage corresponding to national employment (net of social security contributions),  $PCINDEX$  is the consumer price index,  $UNRATE$  provides the unemployment rate,  $err$  is the error term and  $elasU$  is the unemployment elasticity.

The labour supply is provided by the following equation:

$$LSR = LSRI \cdot \{ [PL \cdot (1 - tyavr) \cdot PCINDEXZ] / [PLZ \cdot (1 - tyavrz) \cdot PCINDEX] \}^{elasLS} \quad (75)$$

where  $LSRI$  is the benchmark level corresponding to the active population,  $tyavr$  is the average personal income tax rate and  $tyavrz$  its benchmark level, and  $PLZ$  and  $PCINDEXZ$  are the benchmark levels corresponding to the nominal national wage and CPI, respectively.  $elasLS$  further provides the elasticity of labour supply.

The average personal income tax rate is determined as:

$$tyavr = \frac{\sum_{qu} (ty_{qu} \cdot YH_{qu})}{\sum_{qu} YH_{qu}}$$

where  $ty_{qu}$  stands for the personal income tax rate levied on the household income group  $qu$  and  $YH_{qu}$  gives the total income of the household income group  $qu$ .

The national employment ( $EMPN$ ) is defined as:

$$EMPN = LSR - UNEMP \quad (76)$$

The national average wage including social security contributions ( $PLAVRT$ ) is determined as:

$$PLAVRT \cdot (LSR - UNEMP) = \sum_s [PL \cdot (1 + tl_s / (1 - tl_s)) \cdot (1 + premLSK_s) \cdot LSK_s] \quad (77)$$

where  $PL$  is the national average wage,  $premsLSK_s$  gives the wage premium in sector  $s$  and  $tl_s$  provides the social contributions rate in sector  $s$ .

## 2.10 Market clearing equations

The equilibrium in the product, capital and labour markets requires that demand equals supply at prevailing prices (taking into account unemployment for the labour market). Labour market clearing equation has already been presented above. Capital stock is sector specific, such that the equality between capital demand and supply determines the return to capital by branch of activity.

Separate market clearing equations are distinguished in the model for each commodity  $c$ . For the trade and transport services  $ctm$ , the sum of demand for intermediate consumption of commodity  $ctm$  ( $\sum_s io_{ctm,s} \cdot XD_s$ ), the private demand for commodity  $ctm$  ( $C_{ctm,qu}$ ), the public demand for commodity  $ctm$  ( $CG_{ctm}$ ), the demand for investment goods ( $I_{ctm}$ ), the demand for inventories ( $SV_{ctm}$ ) and the demand for trade and transport services ( $MARGTM_{ctm}$ ) which are invoiced separately (trade and transport margins) should be equal with the total supply of commodity  $ctm$  ( $X_{ctm}$ ) from imports and domestic production:

$$\sum_s io_{ctm,s} \cdot XD_s + \sum_{qu} C_{ctm,qu} + CG_{ctm} + I_{ctm} + SV_{ctm} + MARGTM_{ctm} = X_{ctm} \quad (78)$$

The demand for trade and transport services  $ctm$  ( $MARGTM_{ctm}$ ) invoiced separately (Löfgren, Harris and Robinson, 2002), is further derived as the sum of demand for trade and transport services on private consumption ( $\sum_{c,qu} tchtm_{ctm,c,qu} \cdot C_{c,qu}$ ), of demand for trade and transport services on investment goods ( $\sum_c tcitm_{ctm,c} \cdot I_c$ ) and of demand for trade and transport services on intermediate consumption ( $\sum_{s,c} tcictm_{ctm,c,s} \cdot io_{c,s} \cdot XD_s$ ):

$$MARGTM_{ctm} = \sum_{c,qu} tchtm_{ctm,c,qu} \cdot C_{c,qu} + \sum_c tcitm_{ctm,c} \cdot I_c + \sum_{s,c} tcictm_{ctm,c,s} \cdot io_{c,s} \cdot XD_s \quad (79)$$

The market clearing equations corresponding to all commodities  $nctm$ , except the trade and transport services are given by:

$$\sum_s io_{nctm,s} \cdot XD_s + \sum_{qu} C_{nctm,qu} + CG_{nctm} + I_{nctm} + SV_{nctm} = X_{nctm} \quad (80)$$

The demand for inventories for each commodity  $c$  is defined as a fixed share of domestic sales:

$$SV_c = svr_c \cdot X_c \quad (81)$$

## 2.11 Other macroeconomic indicators

Gross domestic product is provided at both constant prices ( $GDP$ ) and at current market prices ( $GDPC$ ):

$$\begin{aligned} GDP = & \sum_{c,qu} \{ C_{c,qu} \cdot [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vatcz_{c,qu}) \} + \\ & \sum_c CG_c \cdot PZ_c + \sum_c \{ I_c \cdot (1 + vati_z_c) \cdot [PZ_c + \sum_{ctm} tcitmz_{ctm,c} \cdot PZ_{ctm}] \} + \sum_c SV_c \cdot PZ_c + \\ & \sum_c EML_c \cdot PEMLZ_c + \sum_c EEU_c \cdot PEEUZ_c + \sum_c EUS_c \cdot PEUSZ_c + \sum_c EROW_c \cdot PEROWZ_c - \\ & \sum_c MML_c \cdot PWMMLZ_c \cdot ERMLZ_c - \sum_c MEU_c \cdot PWMEUZ_c \cdot EREUZ_c - \\ & \sum_c MUS_c \cdot PWMUSZ_c \cdot ERUSZ_c - \sum_c MROW_c \cdot PWMROWZ_c \cdot ERROWZ_c \end{aligned} \quad (82)$$

$$\begin{aligned} GDPC = & \sum_{c,qu} \{ C_{c,qu} \cdot [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatc_{c,qu}) \} + \\ & \sum_c CG_c \cdot P_c + \sum_c \{ I_c \cdot (1 + vati_c) \cdot [P_c + \sum_{ctm} tcitm_{ctm,c} \cdot P_{ctm}] \} + \sum_c SV_c \cdot P_c + \sum_c EML_c \cdot PEML_c \\ & + \sum_c EEU_c \cdot PEEU_c + \sum_c EUS_c \cdot PEUS_c + \sum_c EROW_c \cdot PEROW_c - \\ & \sum_c MML_c \cdot PWMML_c \cdot ERML_c - \sum_c MEU_c \cdot PWMEU_c \cdot EREU_c - \\ & \sum_c MUS_c \cdot PWMUS_c \cdot ERUS_c - \sum_c MROW_c \cdot PWMROW_c \cdot ERROW_c \end{aligned} \quad (83)$$

where  $vati_z_c$  stands for the benchmark level of the value-added tax rate on investment goods,  $PEMLZ_c$ ,  $PEEUZ_c$ ,  $PEUSZ_c$  and  $PEROWZ_c$  provide the benchmark levels of domestic price of exports to Mainland, EU, US and ROW, respectively,  $PWMMLZ_c$ ,  $PWMEUZ_c$ ,  $PWMUSZ_c$  and  $PWMROWZ_c$  give the benchmark levels of the world price of imports from Mainland, EU, US and ROW, respectively, and  $ERMLZ_c$ ,  $EREUZ_c$ ,

*ERUSZ* and *ERROWZ* provide the benchmark levels of the exchange rates with respect to Mainland, EU, US and ROW, respectively.

Derivation of some other macroeconomic indicators like the components of GDP at constant prices and the private GDP at constant prices is provided in section 2.14.

## 2.12 Incorporation of dynamics

AzorMod has a recursive dynamic structure composed of a sequence of several temporary equilibria. The first equilibrium in the sequence is given by the benchmark year. In each time period, the model is solved for an equilibrium given the exogenous conditions assumed for that particular period. The equilibria are connected to each other through capital accumulation. Thus, the endogenous determination of investment behaviour is essential for the dynamic part of the model. Investment and capital accumulation in year  $t$  depend on expected rates of return for year  $t+1$ , which are determined by actual returns on capital in year  $t$ .

The normal rate of return to capital in branch  $s$  ( $ROR_s$ ) is specified as an inverse logistic function (see Figure 5) of the proportionate growth in sector's  $s$  capital stock (Dixon and Rimmer, 2002):

$$ROR_{s,t} = RORH_s + (1/B_s) \cdot [\ln(KSKg_{s,t} - KSKg\ min_s) - \ln(KSKg\ max_s - KSKg_{s,t}) - \ln(KSKtrend_s - KSKg\ min_s) + \ln(KSKg\ max_s - KSKtrend_s)] \quad (84)$$

where  $RORH_s$  is the historically normal rate of return in branch  $s$ ,  $KSKg_{s,t}$  is the capital growth rate in industry  $s$  in year  $t$ ,  $KSKg\ min_s$  and  $KSKg\ max_s$  are the minimum and the maximum possible growth rates of capital stock in branch  $s$ ,  $KSKtrend_s$  is the industry's historically normal growth rate and  $B_s$  is a positive parameter. The minimum possible growth rate is set at the negative of the rate of depreciation in branch  $s$ . This condition implies that investments in each branch of activity have positive values, such that once installed, capital cannot be shifted from one sector to another except for the gradual process of depreciation. The maximum possible growth rate of capital stock in industry  $s$  is set at  $KSKtrend_s$  plus  $lim\ INV_s$  in order to avoid unrealistically large simulated growth rates (Dixon and Rimmer, 2002). In the current version  $lim\ INV_s$  is taken equal to 6 per cent for all the branches. For example, if the historically normal growth rate in an industry is 4 per cent, the upper limit in any year  $t$  would not exceed 10 per cent.

Parameter ( $B_s$ ) reflects the sensitivity of capital growth in branch  $s$  to variations in its expected rate of return. It is derived by differentiating equation (84) with respect to  $KSKg_{s,t}$ :

$$B_s = SEA \cdot \left[ \frac{KSKg\ max_s - KSKg\ min_s}{(KSKg\ max_s - KSKtrend_s) \cdot (KSKtrend_s - KSKg\ min_s)} \right] \quad (85)$$

where:

$$SEA = \left( \frac{\partial ROR_{s,t}}{\partial KSKg_{s,t}} \right)^{-1} \quad (86)$$

Evaluating (86) in the neighbourhood of  $KSKg_{s,t} = KSKtrend_s$  provides:

$$SEA = \left( \frac{\partial ROR_{s,t}}{\partial KSKg_{s,t}} \Big|_{KSKg_{s,t} = KSKtrend_s} \right)^{-1} \quad (87)$$

where  $SEA$  is the reciprocal of the slope of the  $RR'$  in Figure 5, which is considered to be the same for all industries due to the lack of detailed estimates by branch.

The present value ( $PVK_{s,t}$ ) of investing a unit of capital in industry  $s$  in year  $t$  is defined as:

$$PVK_{s,t} = -PI_t + [PK_{s,t+1} + PI_{t+1} \cdot d_s + PI_{t+1} \cdot (1 - d_s)] / [1 + NINT_t] \quad (88)$$

where  $PI_t$  is the cost of buying a unit of capital (the price of composite investment good) in year  $t$ ,  $PK_{s,t} + PI_{t+1} \cdot d_s$  is the rental rate on industry's  $s$  capital stock,  $d_s$  is the depreciation rate in branch  $s$  and  $NINT_t$  is the nominal interest rate in year  $t$  (Dixon and Rimmer, 2002). The purchase of one unit of capital in year  $t$  by industry  $s$  involves an immediate expenditure ( $PI_t$ ), followed by two benefits in year  $t+1$  which are discounted by  $(1 + NINT_t)$ : the rental value of an extra unit of capital in year  $t+1$  ( $PK_{s,t+1} + PI_{t+1} \cdot d_s$ ), including the depreciation, and the value at which the depreciated unit of capital can be sold in year  $t+1$  [ $PI_{t+1} \cdot (1 - d_s)$ ].

The expected rate of return on investment in industry  $s$  in year  $t$  is given by dividing both sides of (88) by  $PI_t$ :

$$ROR_{s,t} = -1 + [PK_{s,t+1} / PI_t + PI_{t+1} / PI_t] / [1 + NINT_t] \quad (89)$$

Under static expectations, investors are assumed to anticipate that the asset prices (the cost of buying a unit of capital) and the net rental rates will increase by the current rate of inflation ( $RINF_t$ ). Thus, the expected rate of return ( $ROR_{s,t}$ ) under static expectations is given by:

$$ROR_{s,t} = -1 + [PK_{s,t} \cdot (1 + RINF_t) / PI_t + PI_t \cdot (1 + RINF_t) / PI_t] / [1 + NINT_t] \quad (90)$$

Simplifying further, we get:

$$ROR_{s,t} = -1 + [PK_{s,t} / PI_t + 1] / (1 + RINT_t) \quad (91)$$

where the real interest rate ( $RINT_t$ ) is defined as:

$$1 + RINT_t = (1 + NINT_t) / (1 + RINF_t) \quad (92)$$

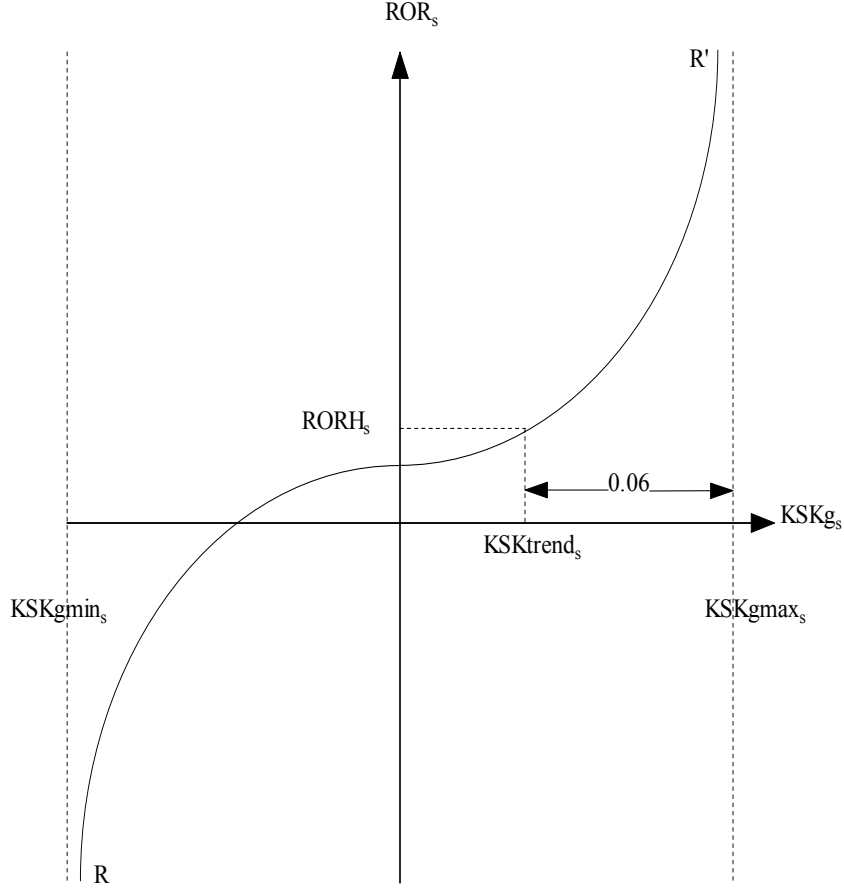


Figure 5. The expected rate of return for industry  $s$

The weighted average real return to capital has been taken as a proxy for the real interest rate in AzorMod. The return to capital is expressed in real terms using the production price index:

$$RINT_t = \sum_s [(PK_{s,t} / PD_{s,t}) \cdot KSK_{s,t}] / \sum_s KSK_{s,t} \quad (93)$$

The capital stock in industry  $s$  in the next period (year  $t+1$ ) is given by:

$$KSK_{s,t+1} = (1 - d_s) \cdot KSK_{s,t} + INV_{s,t} \quad (94)$$

where  $KSK_{s,t}$  is the current capital stock (in year  $t$ ) and  $INV_{s,t}$  stand for the investments by the branch  $s$  in year  $t$ .

The capital growth rate in terms of capital stock in year  $t+1$  and the capital stock in year  $t$  is given by:

$$KSKg_{s,t} = KSK_{s,t+1} / KSK_{s,t} - 1 \quad (95)$$

whereas the actual growth rate of capital in industry  $s$  can be derived from equation. (84) as:

$$KSKg_{s,t} = \left[ \alpha ROR_{s,t} \cdot KSKg_{max_s} \cdot (KSKtrend_s - KSKg_{min_s}) + KSKg_{min_s} \cdot (KSKg_{max_s} - KSKtrend_s) \right] / \left[ \alpha ROR_{s,t} \cdot (KSKtrend_s - KSKg_{min_s}) + (KSKg_{max_s} - KSKtrend_s) \right] \quad (96)$$

The parameter  $\alpha ROR_{s,t}$  is given by:

$$\alpha ROR_{s,t} = e^{(((ROR_{s,t} - RORH_s) \cdot (KSKgmax_s - KSKgmin_s)) / ((KSKgmax_s - KSKtrend_s) \cdot (KSKtrend_s - KSKgmin_s)))} \quad (97)$$

A first estimate of investments in the branch  $s$  in year  $t$  ( $INVS_{s,t}$ ) is derived from equations (94)-(96) as:

$$INVS_{s,t} = KSK_{s,t} \cdot [ \alpha ROR_{s,t} \cdot KSKgmax_s \cdot (KSKtrend_s - KSKgmin_s) + KSKgmin_s \cdot (KSKgmax_s - KSKtrend_s) ] / [ \alpha ROR_{s,t} \cdot (KSKtrend_s - KSKgmin_s) + (KSKgmax_s - KSKtrend_s) ] + d_s \cdot KSK_{s,t} \quad (98)$$

while the actual level of investments in branch  $s$  in year  $t$  is provided by:

$$INV_{s,t} = INVS_{s,t} / \sum_{ss} INVS_{ss,t} \cdot (S_t - \sum_c SV_{c,t} \cdot P_{c,t}) / PI_t \quad (99)$$

which also insures the consistency between total investments and savings.

The model is solved dynamically with annual steps. The simulation horizon of the model has been set at 13 years but it can easily be extended.

### 2.13 Closure rules

The closure rules refer to the manner in which demand and supply of commodities, the macroeconomic identities and the factor markets are equilibrated ex-post. Due to the complexity of the model, a combination of closure rules is needed. The particular set of closure rules should also be consistent, to the largest extent possible, with the institutional structure of the economy and with the purpose of the model.

In mathematical terms, the model should consist of an equal number of independent equations and endogenous variables. The closure rules reflect the choice of the model builder of which variables are exogenous and which variables are endogenous, so as to achieve ex-post equality.

Three macro balances are usually identified in CGE models that can be a potential source of ex-ante disequilibria and must be reconciled ex-post (Adelman and Robinson, 1989):

- The savings-investment balance;
- The government balance;
- The external balance.

The most widely used macro closure rule for CGE models is based on the investment and savings balance. In the model, the investment is assumed to adjust to the available domestic and foreign savings. This reflects an economy in which savings form a binding constraint.

Additional assumptions are needed with regard to regional government behaviour in AzorMod. First, regional government savings are fixed in real terms while regional government total current consumption adjusts to achieve the target set with respect to the government savings. The allocation between the consumption of different goods and services is provided by a Cobb-Douglas function. Secondly, the transfers received by the regional government from the Mainland government, from the EU, from the US and from the ROW are fixed in real terms. On the expenditure side, the regional government transfers to the households are also fixed in real terms.

For the external balance, the exchange rates are kept unchanged in the simulations, while the balances of the current accounts adjust. An alternative closure is also possible where

the balances of the current accounts corresponding to US and ROW are set while the real exchange rates adjust.

The setup of the closure rules is important in determining the mechanisms governing the model. Therefore, the closure rules should be established also taking into account the policy scenario in question.

According to Walras' law if  $(n-1)$  markets are cleared the  $n$ th one is cleared as well. Therefore, in order to avoid over-determination of the model, the current account balance with respect to ROW has been dropped (see equation (61), section 2.6). However, the system of equations guarantees, through Walras' law, that the total imports from ROW less the total exports to ROW and the transfers from ROW equals the current account balance.

## 2.14 Model equations

### 2.14.1 Firms

$$SF = shYKF \cdot \sum_s PK_s \cdot KSK_s \quad (A.1)$$

$$KL_s = aKL_s \cdot XD_s \quad (A.2)$$

$$KSK_s = KL_s \cdot \{PKL_s/[PK_s \cdot (1+tk_s) + d_s \cdot PI]\}^{\sigma F_s} \cdot \gamma FK_s^{\sigma F_s} \cdot aF_s^{(\sigma F_s - 1)} \quad (A.3)$$

$$LSK_s = KL_s \cdot \{PKL_s/[PL \cdot (1+premLSK_s) \cdot (1+tl_s/(1-tl_s))]\}^{\sigma F_s} \cdot \gamma FL_s^{\sigma F_s} \cdot aF_s^{(\sigma F_s - 1)} \quad (A.4)$$

$$PKL_s \cdot KL_s = PK_s \cdot (1+tk_s) \cdot KSK_s + PL \cdot (1+premLSK_s) \cdot (1+tl_s/(1-tl_s)) \cdot LSK_s + DEP_s \cdot PI \quad (A.5)$$

$$PD_s \cdot (1-tp_s + tsp_s + tspeuea_s \cdot MUtspeu + tspeufi_s \cdot MUtspeu + tspeuer_s \cdot MUtspeu + tspeues_s \cdot MUtspeu + tspusa_s) \cdot XD_s = PKL_s \cdot KL_s + \sum_c \{io_{c,s} \cdot XD_s \cdot [(1-tsic_{c,s}) \cdot P_c + \sum_{ctm} tcictm_{ctm,c,s} \cdot P_{ctm}] \cdot (1+vatic_{c,s})\} \quad (A.6)$$

### 2.14.2 Households

$$[P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1+texc_{c,qu}) \cdot (1+tc_{c,qu} + vatic_{c,qu}) \cdot C_{c,qu} = [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1+texc_{c,qu}) \cdot (1+tc_{c,qu} + vatic_{c,qu}) \cdot \mu H_{c,qu} + \alpha H_{c,qu} \cdot \{CBUD_{qu} - \sum_{cc} [P_{cc} + \sum_{ctm} tchtm_{ctm,cc,qu} \cdot P_{ctm}] \cdot (1+texc_{cc,qu}) \cdot (1+tc_{cc,qu} + vatic_{cc,qu}) \cdot \mu H_{cc,qu}\} \quad (A.7)$$

$$YH_{qu} = shYKH_{qu} \cdot \sum_s PK_s \cdot KSK_s + shYLH_{qu} \cdot \sum_s PL \cdot (1+premLSK_s) \cdot LSK_s + TRHML_{qu} \cdot ERML + shUNEMPB_{qu} \cdot trep \cdot PL \cdot UNEMP + TRHG_{qu} \cdot PCINDEX \quad (A.8)$$

$$CBUD_{qu} = (1-ty_{qu}) \cdot YH_{qu} - SH_{qu} \quad (A.9)$$

$$SH_{qu} = MPS_{qu} \cdot (1-ty_{qu}) \cdot YH_{qu} \quad (A.10)$$

$$MPS_{qu} = MPSZ_{qu} \cdot \{[(1-ty_{qu}) \cdot PKavr]/[(1-tyz_{qu}) \cdot PKavrZ]\}^{elas_{qu}} \quad (A.11)$$

### 2.14.3 Regional government

$$GREV = TRPROP + TRPROD + TRANSR \quad (A.12)$$

$$TRPROP = \sum_{qu} ty_{qu} \cdot YH_{qu} + \sum_s tk_s \cdot KSK_s \cdot PK_s \quad (A.13)$$

$$TRPROD = \sum_s tp_s \cdot XD_s \cdot PD_s + \sum_{c,qu} \{ [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot [texc_{c,qu} + (1+texc_{c,qu}) \cdot (tc_{c,qu} + vatic_{c,qu})] \cdot C_{c,qu} \} + \sum_c [P_c + \sum_{ctm} tcitm_{ctm,c} \cdot P_{ctm}] \cdot vatic_c \cdot I_c + \sum_{c,s} [(1-tsic_{c,s}) \cdot P_c + \sum_{ctm} tcictm_{ctm,c,s} \cdot P_{ctm}] \cdot vatic_{c,s} \cdot io_{c,s} \cdot XD_s + \sum_c (tmus_c \cdot PWMUS_c \cdot MUS_c \cdot ERUS) + \sum_c (tmrw_c \cdot PWMROW_c \cdot MROW_c \cdot ERROW) \quad (A.14)$$

$$TRANSR = TRGML \cdot ERML + TRGEU \cdot EREU + TRGEC \cdot EREU + TRGUS \cdot ERUS + TRGW \cdot ERROW \quad (A.15)$$

$$GEXP = CGBUD + TRANS + SUBSID \quad (A.16)$$

$$P_c \cdot CG_c = \alpha CG_c \cdot CGBUD \quad (A.17)$$

$$TRANS = \sum_{qu} TRHG_{qu} \cdot PCINDEX \quad (A.18)$$

$$SUBSID = \sum_{c,s} tsic_{c,s} \cdot P_c \cdot io_{c,s} \cdot XD_s + \sum_s [(tsp_s + tspeuea_s \cdot MUtspeu + tspeufi_s \cdot MUtspeu + tspeuer_s \cdot MUtspeu + tspeues_s \cdot MUtspeu + tspusa_s) \cdot XD_s \cdot PD_s] \quad (A.19)$$

$$TRGEC \cdot EREU = MUtspeu \cdot \sum_s [(tspeuea_s + tspeufi_s + tspeuer_s + tspeues_s) \cdot XD_s \cdot PD_s] \quad (A.20)$$

$$SG \cdot GDPDEF = GREV - GEXP \quad (A.21)$$

$$rTRPROPGDP = TRPROP/GDPC \cdot 100 \quad (A.22)$$

$$rTRPRODGDGP = TRPROD/GDPC \cdot 100 \quad (A.23)$$

$$rTRANSRGDP = TRANSR/GDPC \cdot 100 \quad (A.24)$$

$$rCGBUDGDGP = CGBUD/GDPC \cdot 100 \quad (A.25)$$

$$rTRANSGDGP = TRANS/GDPC \cdot 100 \quad (A.26)$$

$$rSUBSIDGDGP = SUBSID/GDPC \cdot 100 \quad (A.27)$$

$$rSGGDGP = SG \cdot GDPDEF/GDPC \cdot 100 \quad (A.28)$$

#### 2.14.4 Mainland government

$$SGML = \sum_s [tl_s / (1 - tl_s) \cdot LSK_s \cdot PL \cdot (1 + premLSK_s) / ERML] - \sum_{qu} TRHML_{qu} - \sum_{qu} (shUNEMP_{qu} \cdot trep \cdot PL \cdot UNEMP / ERML) - TRGML \quad (A.29)$$

#### 2.14.5 European Commission

$$SGEC = -TRGEC - TRGEU \quad (A.30)$$

#### 2.14.6 Domestic supply to domestic and foreign markets

$$XDDE_c = \sum_s ioC_{s,c} \cdot XD_s \quad (A.31)$$

$$PD_s = \sum_c ioC_{s,c} \cdot PDDE_c \quad (A.32)$$

#### 2.14.7 Foreign sector

$$EML_c = XDDE_c \cdot (PDDE_c / PEML_c)^{\sigma T_c} \cdot \gamma T_1^{\sigma T_c} \cdot a T_c^{(\sigma T_c - 1)} \quad (A.33)$$

$$EEU_c = XDDE_c \cdot (PDDE_c / PEEU_c)^{\sigma T_c} \cdot \gamma T_2^{\sigma T_c} \cdot a T_c^{(\sigma T_c - 1)} \quad (A.34)$$

$$EUS_c = XDDE_c \cdot (PDDE_c / PEUS_c)^{\sigma T_c} \cdot \gamma T_3^{\sigma T_c} \cdot a T_c^{(\sigma T_c - 1)} \quad (A.35)$$

$$EROW_c = XDDE_c \cdot (PDDE_c/PEROW_c)^{\sigma T_c} \cdot \gamma T4_c^{\sigma T_c} \cdot aT_c^{(\sigma T_c - 1)} \quad (A.36)$$

$$XDD_c = XDDE_c \cdot (PDDE_c/PDD_c)^{\sigma T_c} \cdot \gamma T5_c^{\sigma T_c} \cdot aT_c^{(\sigma T_c - 1)} \quad (A.37)$$

$$PDDE_c \cdot XDDE_c = PDD_c \cdot XDD_c + PEML_c \cdot EML_c + PEEU_c \cdot EEU_c + PEUS_c \cdot EUS_c + PEROW_c \cdot EROW_c \quad (A.38)$$

$$E_c = (PEML_c \cdot EML_c + PEEU_c \cdot EEU_c + PEUS_c \cdot EUS_c + PEROW_c \cdot EROW_c) / INDEXE_c \quad (A.39)$$

$$EDML_c = EDIML_c \cdot (PWEML_c \cdot ERML/PEML_c)^{elasE_c} \quad (A.40)$$

$$EDEU_c = EDIEU_c \cdot (PWEEU_c \cdot EREU/PEEU_c)^{elasE_c} \quad (A.41)$$

$$EDUS_c = EDIUS_c \cdot (PWEUS_c \cdot ERUS/PEUS_c)^{elasE_c} \quad (A.42)$$

$$EDROW_c = EDIROW_c \cdot (PWEROW_c \cdot ERROW/PEROW_c)^{elasE_c} \quad (A.43)$$

$$MML_c = X_c \cdot (P_c/PMML_c)^{\sigma A_c} \cdot \gamma A1_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (A.44)$$

$$MEU_c = X_c \cdot (P_c/PMEU_c)^{\sigma A_c} \cdot \gamma A2_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (A.45)$$

$$MUS_c = X_c \cdot (P_c/PMUS_c)^{\sigma A_c} \cdot \gamma A3_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (A.46)$$

$$MROW_c = X_c \cdot (P_c/PMROW_c)^{\sigma A_c} \cdot \gamma A4_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (A.47)$$

$$XDD_c = X_c \cdot (P_c/PDD_c)^{\sigma A_c} \cdot \gamma A5_c^{\sigma A_c} \cdot aA_c^{(\sigma A_c - 1)} \quad (A.48)$$

$$P_c \cdot X_c = PMML_c \cdot MML_c + PMEU_c \cdot MEU_c + PMUS_c \cdot MUS_c + PMROW_c \cdot MROW_c + PDD_c \cdot XDD_c \quad (A.49)$$

$$M_c = (PVMML_c \cdot ERML \cdot MML_c + PVMEU_c \cdot EREU \cdot MEU_c + PWMUS_c \cdot ERUS \cdot MUS_c + PWMROW_c \cdot ERROW \cdot MROW_c) / INDEXM_c \quad (A.50)$$

$$SML = \sum_c (MML_c \cdot PVMML_c - EML_c \cdot PEML_c / ERML) + SGML \quad (A.51)$$

$$SEU = \sum_c (MEU_c \cdot PVMEU_c - EEU_c \cdot PEEU_c / EREU) + SGEC \quad (A.52)$$

$$SUS = \sum_c (MUS_c \cdot PWMUS_c - EUS_c \cdot PEUS_c / ERUS) - TRGUS \quad (A.53)$$

$$SROW = \sum_c (MROW_c \cdot PWMROW_c - EROW_c \cdot PEROW_c / ERROW) - TRGW \quad (A.54)$$

## 2.14.8 Investment

$$S = \sum_{qu} SH_{qu} + SF + SG \cdot GDPDEF + SML \cdot ERML + SEU \cdot EREU + SUS \cdot ERUS + SROW \cdot ERROW + \sum_s DEP_s \cdot PI \quad (A.55)$$

$$I_c = ioI_c \cdot ITT \quad (A.56)$$

$$PI = \sum_c \{ (1 + vati_c) \cdot [P_c + \sum_{ctm} tcitm_{ctm,c} \cdot P_{ctm}] \cdot ioI_c \} \quad (A.57)$$

$$PI \cdot ITT = S - \sum_c SV_c \cdot P_c \quad (A.58)$$

$$SV_c = svr_c \cdot X_c \quad (A.59)$$

$$DEP_s = d_s \cdot KSK_s \quad (A.60)$$

#### 2.14.9 Labor market

$$\log(PL/PCINDEX) = elasU \cdot \log(UNRATE) + err \quad (A.61)$$

$$LSR = LSRI \cdot \{ [PL \cdot (1 - tyavr) \cdot PCINDEXZ] / [PLZ \cdot (1 - tyavrz) \cdot PCINDEX] \}^{elasLS} \quad (A.62)$$

$$tyavr = \sum_{qu} (ty_{qu} \cdot YH_{qu}) / \sum_{qu} YH_{qu} \quad (A.63)$$

$$EMP_N = LSR - UNEMP \quad (A.64)$$

$$UNRATE = UNEMP / LSR \quad (A.65)$$

#### 2.14.10 Trade and transport margins

$$MARGTM_{ctm} = \sum_{c,qu} tchtm_{ctm,c,qu} \cdot C_{c,qu} + \sum_c tcitm_{ctm,c} \cdot I_c + \sum_{s,c} tcictm_{ctm,c,s} \cdot io_{c,s} \cdot XD_s \quad (A.66)$$

#### 2.14.11 Market clearing

$$\sum_s LSK_s = LSR - UNEMP \quad (A.67)$$

$$\sum_s io_{ctm,s} \cdot XD_s + \sum_{qu} C_{ctm,qu} + CG_{ctm} + I_{ctm} + SV_{ctm} + MARGTM_{ctm} = X_{ctm} \quad (A.68)$$

$$\sum_s io_{nctm,s} \cdot XD_s + \sum_{qu} C_{nctm,qu} + CG_{nctm} + I_{nctm} + SV_{nctm} = X_{nctm} \quad (A.69)$$

$$EML_c = EDML_c \quad (A.70)$$

$$EEU_c = EDEU_c \quad (A.71)$$

$$EUS_c = EDUS_c \quad (A.72)$$

$$EROW_c = EDROW_c \quad (A.73)$$

#### 2.14.12 Price definitions

$$PCINDEX = \sum_{c,qu} \{ [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatc_{c,qu}) \cdot CZ_{c,qu} \} / \sum_{c,qu} \{ [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vatcz_{c,qu}) \cdot CZ_{c,qu} \} \quad (A.74)$$

$$INDEXE_c = (PEML_c \cdot EMLZ_c + PEEU_c \cdot EEUZ_c + PEUS_c \cdot EUSZ_c + PEROW_c \cdot EROWZ_c) / (PEMLZ_c \cdot EMLZ_c + PEEUZ_c \cdot EEUZ_c + PEUSZ_c \cdot EUSZ_c + PEROWZ_c \cdot EROWZ_c) \quad (A.75)$$

$$INDEXM_c = (PWWML_c \cdot ERML \cdot MMLZ_c + PWMEU_c \cdot EREU \cdot MEUZ_c + PWMUS_c \cdot ERUS \cdot MUSZ_c + PWMROW_c \cdot ERROW \cdot MROWZ_c) / (PWWMLZ_c \cdot ERMLZ \cdot MMLZ_c + PWMEUZ_c \cdot EREUZ \cdot MEUZ_c + PWMUSZ_c \cdot ERUSZ \cdot MUSZ_c + PWMROWZ_c \cdot ERROWZ \cdot MROWZ_c) \quad (A.76)$$

$$PMML_c = PWMML_c \cdot ERML \quad (A.77)$$

$$PMEU_c = PWMEU_c \cdot EREU \quad (A.78)$$

$$PMUS_c = PWMUS_c \cdot ERUS \cdot (1 + tmus_c) \quad (A.79)$$

$$PMROW_c = PWMROW_c \cdot ERROW \cdot (1 + tmrw_c) \quad (A.80)$$

$$RINT = \sum_s [(PK_s/PD_s) \cdot KSK_s] / \sum_s KSK_s \quad (A.81)$$

$$PKavr = \sum_s [(PK_s/PCINDEX) \cdot KSK_s] / \sum_s KSK_s \quad (A.82)$$

$$PCT_{c,qu} = [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatc_{c,qu}) \quad (A.83)$$

$$PLAVRT \cdot (LSR - UNEMP) = \sum_s [PL \cdot (1 + tl_s / (1 - tl_s)) \cdot (1 + premLSK_s) \cdot LSK_s] \quad (A.84)$$

### 2.14.13 Gross domestic product at current and constant market prices

$$\begin{aligned} GDPC = & \sum_{c,qu} \{C_{c,qu} \cdot [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatc_{c,qu})\} + \\ & \sum_c CG_c \cdot P_c + \sum_c \{I_c \cdot (1 + vati_c) \cdot [P_c + \sum_{ctm} tcitm_{ctm,c} \cdot P_{ctm}]\} + \sum_c SV_c \cdot P_c + \sum_c EML_c \cdot PEML_c \\ & + \sum_c EEU_c \cdot PEEU_c + \sum_c EUS_c \cdot PEUS_c + \sum_c EROW_c \cdot PEROW_c - \\ & \sum_c MML_c \cdot PWMML_c \cdot ERML - \sum_c MEU_c \cdot PWMEU_c \cdot EREU - \\ & \sum_c MUS_c \cdot PWMUS_c \cdot ERUS - \sum_c MROW_c \cdot PWMROW_c \cdot ERROW \end{aligned} \quad (A.85)$$

$$\begin{aligned} GDP = & \sum_{c,qu} \{C_{c,qu} \cdot [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vatcz_{c,qu})\} + \\ & \sum_c CG_c \cdot PZ_c + \sum_c \{I_c \cdot (1 + vatiz_c) \cdot [PZ_c + \sum_{ctm} tcitmz_{ctm,c} \cdot PZ_{ctm}]\} + \sum_c SV_c \cdot PZ_c + \\ & \sum_c EML_c \cdot PEMLZ_c + \sum_c EEU_c \cdot PEEUZ_c + \sum_c EUS_c \cdot PEUSZ_c + \sum_c EROW_c \cdot PEROWZ_c - \\ & \sum_c MML_c \cdot PWMMLZ_c \cdot ERMLZ - \sum_c MEU_c \cdot PWMEUZ_c \cdot EREUZ - \\ & \sum_c MUS_c \cdot PWMUSZ_c \cdot ERUSZ - \sum_c MROW_c \cdot PWMROWZ_c \cdot ERROWZ \end{aligned} \quad (A.86)$$

$$\begin{aligned} GDPP = & \sum_{c,qu} \{C_{c,qu} \cdot [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vatcz_{c,qu})\} + \\ & \sum_c \{I_c \cdot (1 + vatiz_c) \cdot [PZ_c + \sum_{ctm} tcitmz_{ctm,c} \cdot PZ_{ctm}]\} + \sum_c SV_c \cdot PZ_c + \sum_c EML_c \cdot PEMLZ_c + \\ & \sum_c EEU_c \cdot PEEUZ_c + \sum_c EUS_c \cdot PEUSZ_c + \sum_c EROW_c \cdot PEROWZ_c - \\ & \sum_c MML_c \cdot PWMMLZ_c \cdot ERMLZ - \sum_c MEU_c \cdot PWMEUZ_c \cdot EREUZ - \\ & \sum_c MUS_c \cdot PWMUSZ_c \cdot ERUSZ - \sum_c MROW_c \cdot PWMROWZ_c \cdot ERROWZ \\ GDPDF = & GDPC/GDP \end{aligned} \quad (A.87)$$

#### 2.14.14 Components of GDP at constant prices

$$CT = \sum_{c,qu} \{ C_{c,qu} \cdot [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vatz_{c,qu}) \} \quad (A.88)$$

$$CGT = \sum_c CG_c \cdot PZ_c \quad (A.89)$$

$$IT = \sum_c \{ I_c \cdot (1 + vatiz_c) \cdot [PZ_c + \sum_{ctm} tcitmz_{ctm,c} \cdot PZ_{ctm}] \} + \sum_c SV_c \cdot PZ_c \quad (A.90)$$

$$ET = \sum_c (EML_c \cdot PEMLZ_c + EEU_c \cdot PEEUZ_c + EUS_c \cdot PEUSZ_c + EROW_c \cdot PEROWZ_c) \quad (A.91)$$

$$MT = \sum_c (MML_c \cdot PWMMLZ_c \cdot ERMLZ + MEU_c \cdot PWMEUZ_c \cdot EREUZ + MUS_c \cdot PWMUSZ_c \cdot ERUSZ + MROW_c \cdot PWMROWZ_c \cdot ERROWZ) \quad (A.92)$$

#### 2.14.15 Equivalent variation in income

$$VU_{qu} = \{ CBUD_{qu} - \sum_c [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatic_{c,qu}) \cdot \mu H_{c,qu} \} \cdot \prod_c \{ \alpha H_{c,qu} / \{ [P_c + \sum_{ctm} tchtm_{ctm,c,qu} \cdot P_{ctm}] \cdot (1 + texc_{c,qu}) \cdot (1 + tc_{c,qu} + vatic_{c,qu}) \} \}^{\alpha H_{c,qu}} \quad (A.93)$$

$$VUI_{qu} = \{ CBUDZ_{qu} - \sum_c [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vaticz_{c,qu}) \cdot \mu H_{c,qu} \} \cdot \prod_c \{ \alpha H_{c,qu} / \{ [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vaticz_{c,qu}) \} \}^{\alpha H_{c,qu}} \quad (A.94)$$

$$EV_{qu} = \prod_c \{ \{ [PZ_c + \sum_{ctm} tchtmz_{ctm,c,qu} \cdot PZ_{ctm}] \cdot (1 + texcz_{c,qu}) \cdot (1 + tcz_{c,qu} + vaticz_{c,qu}) \} / \alpha H_{c,qu} \}^{\alpha H_{c,qu}} \cdot (VU_{qu} - VUI_{qu}) \quad (A.95)$$

#### 2.14.16 Capital accumulation

$$ROR_{s,t} = -1 + (PK_{s,t} / PI_t + 1) / (1 + RINT_t) \quad (A.96)$$

$$\alpha ROR_{s,t} = e^{[(ROR_{s,t} - ROR_s) \cdot (KSKgmax_s - KSKgmin_s)] / [(KSKgmax_s - KSKtrend_s) \cdot (KSKtrend_s - KSKgmin_s)]} \quad (A.97)$$

$$INVS_{s,t} = KSK_{s,t} \cdot [ \alpha ROR_{s,t} \cdot KSKgmax_s \cdot (KSKtrend_s - KSKgmin_s) + KSKgmin_s \cdot (KSKgmax_s - KSKtrend_s) ] / [ \alpha ROR_{s,t} \cdot (KSKtrend_s - KSKgmin_s) + (KSKgmax_s - KSKtrend_s) ] + d_s \cdot KSK_{s,t} \quad (A.98)$$

$$INV_{s,t} = INVS_{s,t} / \sum_{ss} INVS_{ss,t} \cdot (S_t - \sum_c SV_{c,t} \cdot P_{c,t}) / PI_t \quad (A.99)$$

$$KSK_{s,t+1} = (1 - d_s) \cdot KSK_{s,t} + INV_{s,t} \quad (A.100)$$

### 2.15 Endogenous variables

CBUD <sub>qu</sub>	households budget disposable for consumption by income group
C <sub>c,qu</sub>	consumer demand for commodity <i>c</i> by income group <i>qu</i>
CGBUD	regional government current expenditures

CG <sub>c</sub>	public current consumption of commodity <i>c</i> by the regional government
CGT	total public consumption by the regional government at constant prices
CT	total private consumption at constant prices
DEP <sub>s</sub>	depreciation related to public and private capital stock
EDEU <sub>c</sub>	export demand of commodity <i>c</i> from EU
EDML <sub>c</sub>	export demand of commodity <i>c</i> from Mainland
EDROW <sub>c</sub>	export demand of commodity <i>c</i> from the rest of the world
EDUS <sub>c</sub>	export demand of commodity <i>c</i> from US
EEU <sub>c</sub>	export supply of commodity <i>c</i> by the domestic producers to EU
EML <sub>c</sub>	export supply of commodity <i>c</i> by the domestic producers to Mainland
EMPN	national employment
EROW <sub>c</sub>	export supply of commodity <i>c</i> by the domestic producers to the rest of the world
ET	total exports at constant prices
EUS <sub>c</sub>	export supply of commodity <i>c</i> by the domestic producers to US
EV <sub>qu</sub>	equivalent variation in income, by household income group
GDP	gross domestic product at constant prices
GDPC	gross domestic product at current market prices
GDPP	private gross domestic product at constant prices
GEXP	total regional government expenditures
GREV	total regional government revenues
I <sub>c</sub>	demand for investment good <i>c</i>
INDEXE <sub>c</sub>	price index corresponding to exports by type of commodity <i>c</i>
INDEXM <sub>c</sub>	price index corresponding to imports by type of commodity <i>c</i>
INV <sub>s</sub>	investments carried out in branch <i>s</i> (actual level)
INVS <sub>s</sub>	investments carried out in branch <i>s</i> (first estimate)
IT	total gross capital formation at constant prices (including inventories)
ITT	total investments in real terms
KL <sub>s</sub>	value-added by branch
LSK <sub>s</sub>	number of employees in branch <i>s</i>
LSR	active population
MARGTM <sub>ctm</sub>	trade and transport margins
MEU <sub>c</sub>	imports of commodity <i>c</i> from EU
MML <sub>c</sub>	imports of commodity <i>c</i> from Mainland
MPS <sub>qu</sub>	households propensity to save, by income group
MROW <sub>c</sub>	imports of commodity <i>c</i> from the rest of the world
MT	total imports at constant prices
MUS <sub>c</sub>	imports of commodity <i>c</i> from US
P <sub>c</sub>	price level of domestic sales (composite commodities coming from imports and domestic production)
PCINDEX	consumer price index
PCT <sub>c,qu</sub>	consumer prices (including taxes)
PDD <sub>c</sub>	price index of domestic production delivered to home market by type of good <i>c</i>
PDDE <sub>c</sub>	price index of domestic production delivered to home and foreign markets by type of good <i>c</i>

PD <sub>s</sub>	price index of domestic production by branch of activity
PEEU <sub>c</sub>	domestic price of exports to EU received by the domestic producers
PEML <sub>c</sub>	domestic price of exports to Mainland received by the domestic producers
PEROW <sub>c</sub>	domestic price of exports to the rest of the world received by the domestic producers
PEUS <sub>c</sub>	domestic price of exports to US received by the domestic producers
PI	price index corresponding to composite investment good
PK <sub>avr</sub>	real average return to capital received by the household
PKL <sub>s</sub>	price index corresponding to value-added by branch of activity
PK <sub>s</sub>	return to capital by branch of activity
PL	national average wage (excluding social security contributions)
PLAVRT	national average wage (including social security contributions)
PMEU <sub>c</sub>	domestic price of imports from EU
PMML <sub>c</sub>	domestic price of imports from Mainland
PMROW <sub>c</sub>	domestic price of imports from the rest of the world (including tariffs)
PMUS <sub>c</sub>	domestic price of imports from US (including tariffs)
RINT	average return to capital corresponding to firms
ROR <sub>s,t</sub>	normal rate of return to capital
rSGGDP	regional government savings to the GDP ratio
rSUBSIDGDP	total subsidies by the regional government to the GDP ratio
rTRANSGDP	total transfers by the regional government to the GDP ratio
rTRANSRGDP	total transfers received by the regional government to the GDP ratio
rTRPRODGDP	regional government revenues from taxes on products and on production to the GDP ratio
rTRPROPGDP	regional government revenues from taxes on income and wealth to the GDP ratio
S	total savings
SEU	balance of the current account with respect to EU
SF	firms savings
SGEC	net transfers by the European Commission to Azores
SGML	net transfers by the Mainland government to Azores
SH <sub>qu</sub>	households savings by income group
SML	balance of the current account with respect to Mainland
SROW	balance of the current account with respect to ROW
SUBSID	total subsidies by the regional government
SUS	balance of the current account with respect to US
SV <sub>c</sub>	inventories
TRANS	total transfers by the regional government
TRANSR	total transfers received by the regional government
TRPROD	regional government revenues from taxes on products and on production
TRPROP	regional government revenues from taxes on income and wealth
ty <sub>avr</sub>	average personal income tax rate
UNEMP	number of unemployed
UNRATE	unemployment rate

$VU_{qu}$	level of indirect utility corresponding to the households, by income group
$X_c$	domestic sales of composite commodities coming from imports and domestic production
$XDD_c$	domestic production delivered to home market
$XDDE_c$	domestic production delivered to home and foreign markets (by type of commodity)
$XD_s$	domestic production by branch of activity
$YH_{qu}$	households income, by income group
$\alpha ROR_{s,t}$	parameter in the supply of capital function

## 2.16 Exogenous variables

$CZ_{c,qu}$	consumer demand for commodity $c$ (benchmark value)
$EDIEU_c$	export demand of commodity $c$ from EU (benchmark value)
$EDIML_c$	export demand of commodity $c$ from the Mainland (benchmark value)
$EDIROW_c$	export demand of commodity $c$ from the rest of the world (benchmark value)
$EDIUS_c$	export demand of commodity $c$ from US (benchmark value)
$EREU$	exchange rate with respect to EU
$EREUZ$	exchange rate with respect to EU (benchmark value)
$ERML$	exchange rate with respect to Mainland
$ERMLZ$	exchange rate with respect to Mainland (benchmark value)
$ERROW$	exchange rate with respect to the rest of the world
$ERROWZ$	exchange rate with respect to the rest of the world (benchmark value)
$ERUS$	exchange rate with respect to US
$ERUSZ$	exchange rate with respect to US (benchmark value)
$GDPDEF$	GDP deflator
$KSK_s$	capital demand by branch (capital stock)
$LSRI$	active population (benchmark value)
$MPSZ_{qu}$	households propensity to save, by income group (benchmark value)
$PCINDEXZ$	consumer price index (benchmark value)
$PEEUZ_c$	domestic price of exports to EU received by the domestic producers (benchmark value)
$PEMLZ_c$	domestic price of exports to Mainland received by the domestic producers (benchmark value)
$PEROWZ_c$	domestic price of exports to the rest of the world received by the domestic producers (benchmark value)
$PEUSZ_c$	domestic price of exports to US received by the domestic producers (benchmark value)
$PKavrZ$	real average return to capital received by the household (benchmark value)
$PLZ$	national average wage (excluding social security contributions) – benchmark value
$PWEEU_c$	price of exports to EU in foreign currency
$PWEML_c$	price of exports to Mainland in foreign currency
$PWEROW_c$	price of exports to ROW in foreign currency

PWEUS <sub>c</sub>	price of exports to US in foreign currency
PWMEU <sub>c</sub>	price of imports from EU in foreign currency
PWMEUZ <sub>c</sub>	price of imports from EU in foreign currency (benchmark value)
PWMML <sub>c</sub>	price of imports from Mainland in foreign currency
PWMMLZ <sub>c</sub>	price of imports from Mainland in foreign currency (benchmark value)
PWMROW <sub>c</sub>	price of imports from ROW in foreign currency
PWMROWZ <sub>c</sub>	price of imports from ROW in foreign currency (benchmark value)
PWMUS <sub>c</sub>	price of imports from US in foreign currency
PWMUSZ <sub>c</sub>	price of imports from US in foreign currency (benchmark value)
PZ <sub>c</sub>	price level of domestic sales (composite commodities coming from imports and domestic production) – benchmark value
RORH <sub>s</sub>	historically normal rate of return to capital
SG	regional government savings
TRGEC	transfers received by the regional government from EU as direct subsidies on production
TRGEU	other transfers received by the regional government from EU
TRGML	transfers received by the regional government from the Mainland government
TRGUS	transfers received by the regional government from US
TRGW	transfers received by the regional government from the rest of the world
TRHG <sub>qu</sub>	transfers received by the households from the regional government, by income group
TRHML <sub>qu</sub>	transfers received by the households from the Mainland government, by income group
VUI <sub>qu</sub>	level of indirect utility corresponding to the household, by income group (benchmark level)

## 2.17 Other parameters

aA <sub>c</sub>	efficiency parameter in the Armington function for imports
aF <sub>s</sub>	efficiency parameter in the CES production function of the firm
aKL <sub>s</sub>	Leontief parameter - share of value added in domestic production
aT <sub>c</sub>	efficiency parameter in the CET function for exports
d <sub>s</sub>	depreciation rate by branch of activity
elasE <sub>c</sub>	price elasticity of export demand
elasLS	elasticity of labour supply
elasS <sub>qu</sub>	elasticity of private savings with respect to after-tax rate of return, by income group
elasU	unemployment elasticity
err	error term in the wage curve equation
io <sub>c,s</sub>	technical coefficients corresponding to intermediate consumption
ioC <sub>s,c</sub>	shares of domestic production delivered to home and foreign markets by branch of activity and commodity
ioI <sub>c</sub>	Leontief parameter for the investment demand by type of investment good
KSKgmax <sub>s</sub>	maximum possible growth rate of capital stock in branch <i>s</i>

$KSKgmin_s$	minimum possible growth rate of capital stock in branch $s$ (equal to the negative of the rate of depreciation in branch $s$ )
$KSKtrend_s$	industry's historically normal growth rate
$premLSK_s$	wage premium over the average wage in domestic employment by branch
$shUNEMPB_{qu}$	share of unemployment benefits received by the households, by income group
$shYKF$	share of the net operating surplus retained by the firms
$shYKH_{qu}$	share of the net operating surplus received by the households, by income group
$shY LH_{qu}$	share of labour income received by the households, by income group
$svr_c$	share of inventories in domestic sales
$tc_{c,qu}$	tax rate corresponding to other taxes on private consumption of commodity $c$
$tchtm_{ctm,c,qu}$	quantity of commodity $ctm$ as trade and transport services per unit of private consumption
$tchtmz_{ctm,c,qu}$	quantity of commodity $ctm$ as trade and transport services per unit of private consumption (benchmark value)
$tcictm_{ctm,c,s}$	quantity of commodity $ctm$ as trade and transport services per unit of intermediate consumption
$tcitm_{ctm,c}$	quantity of commodity $ctm$ as trade and transport services per unit of investment goods
$tcitmz_{ctm,c}$	quantity of commodity $ctm$ as trade and transport services per unit of investment goods (benchmark value)
$tcz_{c,qu}$	tax rate corresponding to other taxes on private consumption of commodity $c$ (benchmark value)
$texc_{c,qu}$	excise duties rate on private consumption of commodity $c$
$texcz_{c,qu}$	excise duties rate on private consumption of commodity $c$ (benchmark value)
$tk_s$	corporate tax rate in branch $s$
$tl_s$	social security contributions rate in branch $s$
$tmrw_c$	tariff rate applied on imports of commodity $c$ from ROW
$tmus_c$	tariff rate applied on imports of commodity $c$ from US
$tp_s$	tax rate on production in branch $s$
$trep$	replacement rate out of national average wage (net of social security contributions)
$tsic_{c,s}$	subsidy rate on intermediate consumption
$tspeuea_s$	subsidy rate on production from the European Agricultural Guidance and Guarantee Fund (EAGGF)
$tspeuer_s$	subsidy rate on production from the European Regional Development Fund (ERDF)
$tspeues_s$	subsidy rate on production from the European Social Fund (ESF)
$tspeufi_s$	subsidy rate on production from the Financial Instrument for Fisheries Guidance (FIFG)
$tsp_s$	subsidy rate on production in branch $s$
$tspusa_s$	subsidy rate on production from US
$tyavrz$	average personal income tax rate (benchmark level)
$ty_{qu}$	personal income tax rate by income group
$tyz_{qu}$	personal income tax rate by income group (benchmark level)

$\text{vat}_{c,\text{qu}}$	value-added tax rate on private consumption of commodity $c$
$\text{vat}_{c,\text{Z},\text{qu}}$	value-added tax rate on private consumption of commodity $c$ (benchmark value)
$\text{vati}_c$	value-added tax rate on investment good $c$
$\text{vati}_{c,s}$	value-added tax rate on intermediate consumption of commodity $c$
$\text{vatiz}_c$	value-added tax rate on investment goods (benchmark level)
$\alpha\text{CG}_c$	Cobb-Douglas preference parameter in the regional government utility function
$\alpha\text{H}_{c,\text{qu}}$	marginal budget shares in the Stone-Geary utility function
$\gamma\text{A1}_c$	CES distribution parameter for imports from Mainland in the Armington function
$\gamma\text{A2}_c$	CES distribution parameter for imports from EU in the Armington function
$\gamma\text{A3}_c$	CES distribution parameter for imports from US in the Armington function
$\gamma\text{A4}_c$	CES distribution parameter for imports from ROW in the Armington function
$\gamma\text{A5}_c$	CES distribution parameter for the domestic demand from the domestic producers in the Armington function
$\gamma\text{FK}_s$	CES distribution parameter for capital in the production function of the firm
$\gamma\text{FL}_s$	CES distribution parameter for labour in the production function of the firm
$\gamma\text{T1}_c$	CET distribution parameter for exports to Mainland
$\gamma\text{T2}_c$	CET distribution parameter for exports to EU
$\gamma\text{T3}_c$	CET distribution parameter for exports to US
$\gamma\text{T4}_c$	CET distribution parameter for exports to ROW
$\gamma\text{T5}_c$	CET distribution parameter for domestic production delivered to home markets
$\mu\text{H}_{c,\text{qu}}$	subsistence level out of consumer demand for commodities
$\sigma\text{A}_c$	substitution elasticities for the Armington function
$\sigma\text{F}_s$	CES capital-labour substitution elasticities by branch
$\sigma\text{T}_c$	elasticities of transformation in the CET function

## 2.18 List of indices used in the model

$c$	a subscript for one of the commodities (45 types of commodities)
$cc$	the same as $c$ (used for exposition purposes)
$ctm$	a subscript for trade and transport services (7 types of trade and transport services)
$nctm$	a subscript for all the other commodities except trade and transport services (38 types of commodities)
$qu$	a subscript for one of the households income groups (6 households income groups)
$s$	a subscript for one of the production activities (45 branches of activity)
$ss$	the same as $s$ (used for exposition purposes)
$t$	a subscript for year $t$

## References

- Adelman, I., & Robinson, S. (1989). Income distribution and development. In H. Chenery & T. N. Srinivasan (Eds.), *Handbook of development economics*, vol. 2 (pp. 949-1003). Amsterdam: North-Holland.
- Dervis, K., De Melo, J., & Robinson, S. (1982). *General equilibrium models for development policy*. Cambridge, UK: Cambridge University Press.
- Dixon, P.B., & Rimmer, M.T. (2002). Dynamic general equilibrium modeling for forecasting and policy: A practical guide and documentation of MONASH. In R. Blundell, R. Caballero, J.-J. Laffont & T. Persson (Eds.), *Contributions to economic analysis*, vol. 256. Amsterdam: North-Holland.
- Harrison, G.W., & Kriström, B. (1997). *General equilibrium effects of increasing carbon taxes in Sweden*. Retrived from: <http://dmsweb.badm.sc.edu/Glenn/papers/>
- Löfgren, H., Harris, R. L., & Robinson, S. (2002). A standard computable general equilibrium (CGE) in GAMS. *IFPRI, Microcomputers in Policy Research*, 5. Retrived from: <http://www.ifpri.org/pubs/microcom/micro5.htm>.
- Rosenthal, R.E. (2006). *GAMS – A user's guide*. Washington: GAMS Development Corporation.
- Sanz-de-Galdeano, A., & Turunen, J. (2006). The euro area wage curve. *Economics Letters*, 92, 93-98.
- Varian, H.R. (1992). *Microeconomic analysis*. New York: W.W. Norton.