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Working Paper

A multi-country general equilibrium model for the European Union: The basic features and the coding structure

Tübinger Diskussionsbeiträge, No. 83

Provided in Cooperation with:

University of Tuebingen, Faculty of Economics and Social Sciences, School of Business and Economics

Suggested Citation: Ruocco, Anna (1996) : A multi-country general equilibrium model for the European Union: The basic features and the coding structure, Tübinger Diskussionsbeiträge, No. 83, Eberhard Karls Universität Tübingen, Wirtschaftswissenschaftliche Fakultät, Tübingen

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**Wirtschaftswissenschaftliche Fakultät
der Eberhard-Karls-Universität Tübingen**

**A multi-country general equilibrium
model for the European Union:
the basic features and
the coding structure**

Anna Ruocco*



Tübinger Diskussionsbeiträge

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**A multi-country general equilibrium
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the coding structure**

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Diskussionsbeitrag Nr. 83
November 1996

Wirtschaftswissenschaftliches Seminar
Mohlstraße 36, D-72074 Tübingen

* Financial support from the Human Capital and Mobility Programme of the EU (Grant No. ERBCHRX-CT94-0493) is gratefully acknowledged.

1. Preliminary remarks

The aim of this paper is to give a clear and inclusive exposition of the basic features of an applied multi-country general equilibrium model representing 7 of the European countries in order to construct a computer program which allows the computation of fiscal or trade policy simulations.

The work has been done as part of the research project „Economic Modelling for Policy Evaluation in the EU: An AGE Approach“, financed by the Human Capital and Mobility Programme of the EU (Grant N°ERBCHRX - CT94 - 0493), in order to create a common base between all groups working on this project. It can be seen as a starting point. Thereafter each group extends the model by introducing additional complexities, depending on the policy questions at issue.

In addition, we think that this paper could be useful for people who want to begin working with applied general equilibrium models as well. In fact, the emphasis of the paper has been put more on the microfoundation of the model, by trying to show a very straightforward way of assembling a general equilibrium model itself. This paper can be seen, therefore, as a structured framework for general equilibrium systems. There are many ways in which one can implement the same model. We will therefore show the advantages of this approach. Much less attention has been paid to the construction of the data set, which we are currently updating¹. The language that has been used to program the model is GAMS (General Algebraic Modelling System, Brooke, Kendrick and Meeraus (1988)), a high-level modelling system for mathematical programming problems.

The remainder of this paper is organised as follows: in section 2) we illustrate the methodology used throughout the whole model; in section 3), we provide an overview of the features of this disaggregated, multi-country model. We are refereeing here particularly to the model structure presented in Fehr, Rosenberg, and Wiegard (FRW,1995). Nevertheless the way in which the model has been assembled and solved differ substantially. In section 4) and sub-paragraphs we go into the details of the model by presenting and commenting on each single equation of the model; in section 5) we give some hints as to how to use the model in order to perform simulations (in equal-yield or differential tax policy analysis); section 6) provides a brief summary. All the details about the structure of the program are provided in three appendices. Appendix 1 is the complete statement of the GAMS-code. Appendix 1 and 2 provide the calibration procedure and the data set for the production and consumption side respectively.

2. The model formulation

2.1 The general equilibrium conditions.

An Arrow-Debreu general economic equilibrium model could be formulated as a system of equations which have to guarantee that certain conditions are satisfied. For large complicated models, a shortcoming of the GAMS modelling environment lies in the specification of the system of non-linear equations, which are then solved by means of one of the available solvers. Therefore, the task of economists is to specify the model rather than to elaborate on the algorithm. Mis-specification of the model is solely dependent on the accuracy of the modellers. There are no automatic checks of the consistency or the functionality of the model².

¹ The data set has been provided by Fehr, H., Rosenberg, C. and W. Wiegard (1991).

² The MPS algorithm in fact provides a totally different modelling approach. The user should basically learn how to handle the system, but once the model is specified, the checks are made automatically. See Rutherford, T. (1989).

Nevertheless one can also construct one's own solution algorithm by using the GAMS language.

The intention here is just to briefly recall the well-known conditions which have to be satisfied in a general equilibrium framework:

1) *Zero Profit*. One constraint requires that, in equilibrium, no producer earns an „excess“ profit. This condition will be satisfied if we impose the restriction that the price of the good must be equal to marginal cost. The use of this constraint simplifies the specification of equations in each individual nest of the production function.

2) *Market clearing condition on factors and goods markets*. A second equilibrium condition is that for each combination of equilibrium prices and production level, the supply of any commodity (endowment) equals demand by consumers (demand by firms).

3) *Income Balance*. Finally, in equilibrium, the value of each agent's income must equal the value of factor endowments. We always work with utility functions which exhibit non-satiation, so Walras's Law will always hold.

In the approach we used, all the general equilibrium conditions are defined as equality constraints: therefore for the firms total costs are equal to total revenues, total factor demand equals total factor supply and so on. All of these conditions can, in fact, be rewritten as an inequality in which case one should impose slackness conditions between variables and equations. The problem would then be written in its complementary form. This way of formulating the Arrow-Debreu model has been proposed by Mathiesen(1985). By introducing the slackness conditions we make the model more flexible. But one has to be aware that the complementary slackness is a feature of the equilibrium allocation, even though it is not imposed as an equilibrium condition per-se. In other words, it will always be the case that the production sector which operates in the market makes zero profit, while any production sector which earns a negative net return is dismissed. In the same way, any commodity which has a positive price strictly fulfills the market clearing condition (supply equals demand for that good), while any commodity in excess supply has an equilibrium price of zero. Technically, if one would like to formulate the model in this way, we then suggest using the MILES³ solver, which makes the solution of complementary problems quite easy.

2.2 Functional form

In this model we make use of CES functions, where Cobb-Douglas and the Leontief functions are considered as special cases. The only complication which one has to deal with is that, as in all the other applied models, we use nested CES, which are pretty easy to understand at an abstract level, but which can become more tedious when specified in detail.

In order to simplify and expediate the task of modellers, we show briefly how we manage with these types of functions. The idea is simply to separate each step and treat it as a single part. Let us look at the following example. We want to represent a two-stage production function. The firm produces the output Y by combining the use of capital (K) and labour (L), the lower level of the production function, with the use of an intermediate good (E):

$$Y = F(E, g(K, L))$$

³ See Rutherford, T. (1993).

What we always do throughout the program is that, whenever we have a nest, we define an additional fictitious production function, which, in this specific case, can easily be identified by:

$$VA = g(K,L)$$

where VA stands for value added. Therefore we would define a price for VA, P_{va} , which will be set equal to the marginal cost, so that the zero profit condition will be fulfilled. At the top level we then have the firm demand for E and VA:

$$Y=F(E,VA)$$

The market for the VA good is limited to the use that sector Y makes of it. In other words, the total amount of VA produced is demanded by the firm Y. The market equilibrium conditions are therefore implicitly fulfilled because the level of production of VA enters directly into the firm demand for valued added.

The number of variables and equations declared are much higher than in the case in which we solve the nested function in the traditional way. But in this case the structure of the model is very neat and can be easily modified and also understood by people who want to use the model without working out all the tedious and error-prone algebraic relations.

We repeatedly use the cost or expenditure function properties of CES production and utility functions. There are several way in which one can write a CES function. We always use the following form:

$$z = f(x, y) = \left[a^{\frac{1}{\sigma}} x^{(\sigma-1)/\sigma} + b^{\frac{1}{\sigma}} y^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)} \quad (a)$$

Let p and q denote the prices of x and y. Then the associated cost or expenditure function is

$$c(p, q, z) = \left[a p^{(1-\sigma)} + b q^{(1-\sigma)} \right]^{1/(1-\sigma)} z . \quad (b)$$

We always use duality theory to derive demand and supply functions. According to Sheppard's lemma (for cost functions), conditional demands can be derived as

$$x(p, q, z) = \frac{\partial c(\cdot)}{\partial p} = a z \left(\frac{c(\cdot) / z}{p} \right)^{\sigma} \quad (c)$$

$$y(p, q, z) = \frac{\partial c(\cdot)}{\partial q} = b z \left(\frac{c(\cdot) / z}{p} \right)^{\sigma} . \quad (d)$$

For later reference, we also specify the cost function for the Leontief production function

$$z = f(x, y) = \min \left[\frac{x}{a}, \frac{y}{b} \right]. \quad (e)$$

The cost function is

$$c(p, q, z) = [ap + bq]z \quad (f)$$

with

$$x = \frac{\partial c(\cdot)}{\partial p} = az; \quad y = \frac{\partial c(\cdot)}{\partial q} = bz. \quad (g)$$

An explicit derivation of these equations can be found in Varian (3rd edition), or any other advanced micro-text.

3. The model

As said in the introduction, the structure of the model is a standard one. The consumer utility and production structures are summarised by means of two clear tree diagrams. We generally used the same notation for the declared variables as we used in the code⁴. This should facilitate the work of people who want to use the GAMS-code to develop the model itself and run some fiscal or trade policies simulations.

First we describe the production side and derive demand functions for primary factors (labour, capital) and intermediate products (section 3.1). In section 3.2 we specify demand and supply functions for the household side of the model. Sections 3.3 defines the government budget constraint. Finally, the last section presents the model equilibrium conditions for goods and factors.

The model features 8 countries, two primary factors of production and 14 commodities in each country. Let

$$I = (\text{FF, BL, NL, DD, II, UK, DK, ROW})$$

be the country index set and *i* or *ii* an element of it. We represent 7 of the EU countries, namely: France (FF), the aggregate Belgium-Luxembourg (BL), Netherlands (NL), Germany (DD), Italy (II), the aggregate United Kingdom-Ireland (UK), Denmark (DK). To close the model we aggregate all the other countries to a group, called „rest of the world“ (ROW).

The index set for the commodity numbers is:

$$N = (1, 2, \dots, 14) \quad \text{with elements } n \text{ (or } nn).$$

The sectors are namely: Agriculture (1), Energy and water (2), Chemicals (3), Metal products (4), Electric prod. (5), Machinery (6), Office equipment (7), Cars (8), Other motor veh. (9), Food and Drinks (10), Textiles and leather (11), Other man. goods (12), Market services (13), Non-market services (14).

An often used subset is:

$$\text{SUBN} = (1, 2, \dots, 13) \quad \text{with elements } \text{subn} \text{ (or } \text{subnn}).$$

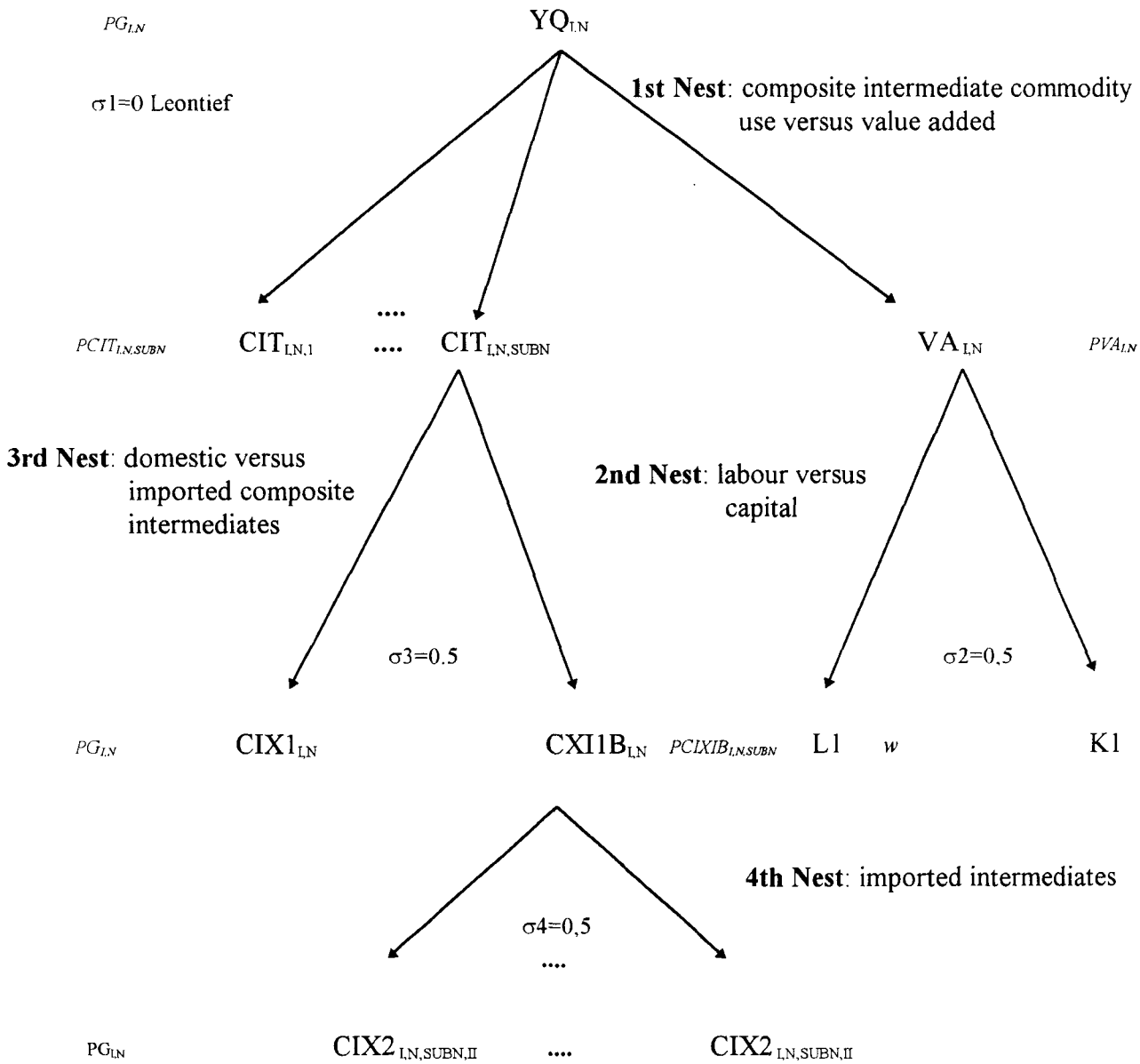
Even if the theoretical structure of the model is straightforward, the notation is somewhat cumbersome. Subscripts *i* (or *ii*) refer to countries, subscripts *n* (or *nn*) refer to commodities or industries. Whenever we use two commodity or country indices, the first one indicates the place of destination, the second the place of origin. For example, the symbol:

$$CIX2_{i,n,\text{subn},ii}$$

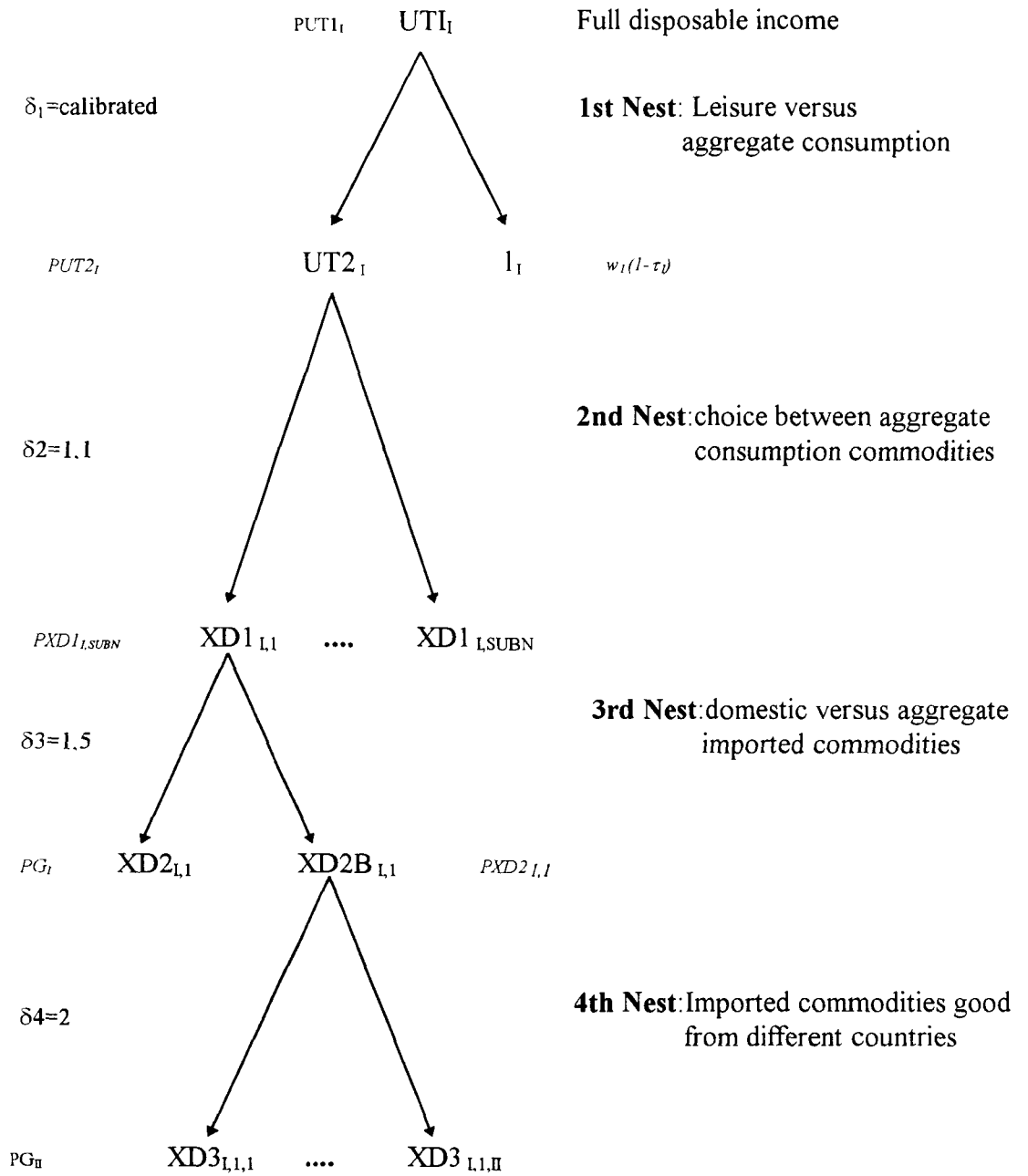
⁴ When they are not the same we indicate the name of the variable used in the code as well.

stands for the intermediate use of commodity subn, originating from country ii, in the production of commodity n in country i. A simplified version of the model is also available on request. The main difference in the structure consist in the definition of the set: N is defined over 3 and I is also defined of 3 countries. The data set in this case is completely unrelated to real data.

**Production sector
CES hierarchy**



Household sector CES hierarchy



3.1 The production sector.

Within each country we identify 13 domestically produced commodities which may be used for domestic consumption, as intermediate inputs in domestic production or as exports. As a 14th commodity, we consider a public good which is produced in quantity G by the public sector. This commodity is not traded, but is consumed (free of charge) by the domestic household sector and is used as an intermediate input (at producer prices) in domestic production. There are two primary production factors, labour and capital. Labour is mobile between production sectors, but not internationally. Capital is homogenous and mobile between production sectors and countries. In addition to primary inputs and domestically produced inputs, firms use intermediates from abroad, which - according to the Armington assumption - might be similar, but not identical to their domestic counterparts.

The firm's decision-making process concerning the use of primary inputs and intermediates is modelled as a hierarchically nested system of constant-return-to-scale production functions. All in all, our model features four such nests: composite intermediate commodity use versus value-added, labour versus capital, domestic versus foreign intermediates and, finally, intermediates from different foreign countries.

The first nest: composite intermediate commodity use versus value added

The production function of industry n in country i is of the Leontief-type:

$$YQ_{i,n} = \text{Min} \left(\frac{VA_{i,n}}{ao_{i,n}}, \frac{CIT_{i,n,m}}{aoci_{i,n,m}} \mid m \in NN \right).$$

According to equations (g) in section 1, we have

$$VA_{i,n} = ao_{i,n} YQ_{i,n} \quad (1)$$

$$CIT_{i,n,m} = aoci_{i,n,m} YQ_{i,n} \quad (2)$$

Let $PVA_{i,n}$ and $PCIT_{i,n,subn}$ be some kind of net of tax „prices“ (or price indices associated with the „quantities“ $VA_{i,n}$ and $CIT_{i,n,m}$. $PVA_{i,n}(1 + \tau_{1,N})$ and $PCIT_{i,n,subn}(1 + \tau_{1,N})$ are the corresponding prices gross of production taxes, where:

$YQ_{i,n}$	level of production
$VA_{i,n}$	value added
$CIT_{i,n,m}$	composite intermediate products
$ao_{i,n}$, $aoci_{i,n,m}$	constant share parameters.
$\tau_{1,N}$	tax rates of production taxes - in the code $TPB_{i,n}$

The cost function is then

$$C_{i,n}(\cdot) = (ao_{i,n} PVA_{i,n} + \sum_m aoci_{i,n,m} PCIT_{i,n,m})(1 + \tau_{1,N}) YQ_{i,n}.$$

Note that the public good ($n=14$) is not traded. Hence, the composite intermediate product $CIT_{i,n,14}$ consists of the domestic public good supply only. Therefore the net of tax price index reduces to where the following notation was used:

$PVA_{i,n}$	price index for $VA_{i,n}$
$PCIT_{i,n,subn}$	price index for $CIT_{i,n,subn}$
$PG_{i,n}$	producer price of commodity n (including production taxes)
$C_{i,n}$	cost function.

Due to the constant returns to scale assumption, average cost $C_{i,n}(\cdot)/YQ_{i,n}$ is equal to marginal cost and equals the producer price $PG_{i,n}$ of the commodity. We therefore have:

$$PG_{i,n} = \left(a_{o,i,n} PVA_{i,n} + \sum_{subn} a_{oci,i,n,subn} PCIT_{i,n,subn} + a_{oci,i,n,14} PG_{i,14} \right) (1 + \tau_{i,n}) \quad (3)$$

The second nest: labour versus capital

We employ a CES function to describe the functional relationship between valued added and the primary production factors:

$$VA_{i,n} = \left[\delta 2_{i,n}^{\frac{1}{\sigma^2}} LD_{i,n}^{(\sigma-1)/\sigma^2} + (1 - \delta 2_{i,n})^{\frac{1}{\sigma^2}} KD_{i,n}^{(\sigma-1)/\sigma^2} \right]^{\sigma^2/(\sigma^2-1)}$$

where

$LD_{i,n}$	labour demand
$KD_{i,n}$	capital demand
$\delta 2_{i,n}$	share parameters
W_i	wage rate (uniform between sectors)
R	rental rate of capital (uniform between sectors and countries)
σ^2	elasticity of substitution between primary factors
$CVA_{i,n}$	cost function.

According to equations (b), (c) and (d) from section 1 we have

$$CVA_{i,n} = \left[\delta 2_{i,n} w_i^{(1-\sigma^2)} + (1 - \delta 2_{i,n}) r^{(1-\sigma^2)} \right]^{1/(1-\sigma^2)} VA_{i,n}$$

or defining

$$PVA_{i,n} := \frac{CVA_{i,n}}{VA_{i,n}}$$

$$PVA_{i,n} = \left[\delta 2_{i,n} w_i^{(1-\sigma^2)} + (1 - \delta 2_{i,n}) r^{(1-\sigma^2)} \right]^{1/(1-\sigma^2)} \quad (4)$$

$$LD_{i,n} = \delta 2_{i,n} VA_{i,n} \left[\frac{PVA_{i,n}}{w_i} \right]^{\sigma^2} \quad (5)$$

$$KD_{i,n} = (1 - \delta 2_{i,n}) VA_{i,n} \left[\frac{PVA_{i,n}}{r} \right]^{\sigma^2} \quad (6)$$

The third nest: domestic versus imported composite intermediates.

At this level, each industry decides how to allocate the composite intermediate input $CIT_{i,n,subn}$ between domestically produced and imported intermediates. Note that this decision concerns the SUBN commodities only (the 14th commodity is not traded).

Define

$CIX1_{i,n,subn}$	domestically produced intermediates
$CIX1B_{i,n,subn}$	imported composite intermediates
$aocix_{i,n,subn}$	share parameter
σ_3	elasticity of substitution between domestic and imported intermediates
$PCIX1B_{i,n,subn}$	price index for $CIX1B_{i,n,subn}$
$CCIT_{i,n,subn}$	cost function

CES function:

$$CIT_{i,n,subn} = \left[aocix_{i,n,subn}^{\frac{1}{\sigma_3}} CIX1_{i,n,subn}^{(\sigma_3-1)/\sigma_3} + (1 - aocix_{i,n,subn})^{\frac{1}{\sigma_3}} CIX1B_{i,n,subn}^{(\sigma_3-1)/\sigma_3} \right]^{\sigma_3 / (\sigma_3 - 1)}$$

Analogous to the second nest, define:

$$PCIT_{i,n,subn} = \frac{CCIT_{i,n,subn}}{CIT_{i,n,subn}}$$

as the per unit cost, which equals the composite price. Per unit cost function and intermediate demands are then given by:

$$PCIT_{i,n,subn} = \left[aocix_{i,n,subn} PG_{i,subn}^{(1-\sigma_3)} + (1 - aocix_{i,n,subn}) PCIX1B_{i,n,subn}^{(1-\sigma_3)} \right]^{1/(1-\sigma_3)} \quad (7)$$

$$CIX1_{i,n,subn} = aocix_{i,n,subn} CIT_{i,n,subn} \left[\frac{PCIT_{i,n,subn}}{PG_{i,subn}} \right]^{\sigma_3} \quad (8)$$

$$CIX1B_{i,n,subn} = (1 - aocix_{i,n,subn}) CIT_{i,n,subn} \left[\frac{PCIT_{i,n,subn}}{PCIX1B_{i,n,subn}} \right]^{\sigma_3} \quad (9)$$

The fourth nest: imported intermediates.

At this last stage the nth industry in country i decides in which country to purchase its intermediate goods. We use the following notation:

$CIX2_{i,n,subn,ii}$	imported intermediate input
$aocix2_{i,n,subn,ii}$	share parameter
$CCIX1B_{i,n,subn}$	cost function
$\Gamma_{i,subn,ii}$	tariffs on intermediate inputs - in the code $TARPB_{i,subn,ii}$
σ_4	elasticity of substitution between imported intermediate inputs

CES function

$$CIX1B_{i,n,subn} = \left(\sum_u aocix2_{i,n,subn,u}^{\frac{1}{\sigma^4}} (CIX2_{i,n,subn,u})^{(\sigma^4-1)/\sigma^4} \right)^{\sigma^4/(\sigma^4-1)}$$

Trade in intermediate inputs between ROW and member states of the EU are subject to tariffs. Tariffs for trade within the EU have been fixed to zero.

The per unit cost function is:

$$PCIX1B_{i,n,subn} := \frac{CCIX1B_{i,n,subn}}{CIX1B_{i,n,subn}}$$

$$PCIX1B_{i,n,subn} = \left(\sum_u aocix2_{i,n,subn,u} (PG_{ii,subn} (1 + \Gamma_{i,subn,ii}))^{(1-\sigma^4)} \right)^{1/(1-\sigma^4)} \quad (10)$$

Demand for intermediate inputs is given by

$$CIX2_{i,n,subn,ii} = aocix2_{i,n,subn,ii} CIX1B_{i,n,subn} \left[\frac{PCIX1B_{i,n,subn}}{PG_{ii,subn} (1 + \Gamma_{i,subn,ii})} \right]^{\sigma^4} \quad (11)$$

This completes the description of the production sector.

3.2. The household sector

We assume only one representative household in each country. In the model, we distinguish four utility nests regarding the choice between leisure and aggregate consumption, different consumption goods, imported and domestic commodities and finally, imported consumption goods from different source countries. Collective consumption goods are provided free of charge and enter the utility function in an additively separable manner (and consequently can be omitted).

In the following, equation (a) from section 1 is interpreted as a CES utility function or utility nest, equation (b) is the corresponding expenditure function and (c) and (d) are the compensated or Hicksian demand functions. Hicksian demand at utility level z (in the first section's terminology) coincides with the Marshallian demand at an income level which equals $c(p,q,z)$.

The first nest: leisure versus aggregate consumption.

The representative consumer in country i solves the following optimization problem

$$\max UT_i = \left[cc_i^{\frac{1}{\delta_1}} UT2_i^{(\delta_1-1)/\delta_1} + cl_i^{\frac{1}{\delta_1}} LL_i^{(1-1)/\delta_1} \right]^{1/(1-\delta_1)}$$

such that:

$$PUT2_i UT2_i + w_i (1 - T_i) LL_i = M_i$$

where full disposable M_i is determined by:

$$M_i = [r KS_i + w_i EB_i] (1 - T_i) + A_i T_i + TR_i QL_i$$

We use the following notation :

UT_i	top utility level
$UT2_i$	second utility level
LL_i	leisure demand
cc_i, cl_i	share parameters
δ	elasticity of substitution
$PUT2_i$	price index for 2nd utility level
w_i	gross wage rate
r	interest rate
KS_i	capital endowment
EB_i	total time endowment
T_i	marginal income tax rate - in the code INCTARB _i
A_i	income tax allowance - ALLOWB _i
TR_i	transfer payment from the government - TRANSFER _i
QL_i	Laspeyres price index (as defined by equation (25))
EUT_i	expenditure function.

The expenditure function is:

$$EUT_i(\cdot) = \left[cl_i (w_i (1 - T_i))^{1-\delta} + cc_i PUT2_i^{1-\delta} \right]^{1/(1-\delta)} UT_i .$$

For later use it is convenient to define:

$$PUT1_i := \frac{EUT_i(\cdot)}{UT_i}$$

such that:

$$PUT1_i = \left[cl_i (w_i (1 - T_i))^{1-\delta} + cc_i PUT2_i^{1-\delta} \right]^{1/(1-\delta)} \quad (12)$$

To guarantee the equivalence of Hicksian and Marshallian demand the following equation must hold:

$$UT_i PUT1_i = M_i .$$

Using the definition of M_i we can write

$$UT_i PUT1_i = r KS_i + w_i EB_i (1 - T_i) + A_i T_i + TR_i QL_i \quad (13)$$

And we can also rewrite the budget constraint as follows:

$$UT_i PUT1_i = UT2_i PUT2_i + w_i (1 - T_i) LL_i \quad (14)$$

Demand for leisure and aggregate consumption are given by

$$LL_i = cl_i UT_i \left[\frac{PUT1_i}{w_i (1 - T_i)} \right]^{\delta} \quad (15)$$

$$UT2_i = c c_i UT_i \left[\frac{PUT1_i}{PUT2_i} \right]^{\delta 1} \quad (16)$$

The second nest: choice between aggregate consumption commodities (only for $subn \in N$ because the public good is received free of charge).

CES utility at the second utility level

$$UT2_i = \left[\sum_{subn} c1_{i,subn} X D1_{i,subn}^{(\delta 2-1)/\delta 2} \right]^{\delta 2/(\delta 2-1)}$$

where:

$X D1_{i,subn}$	aggregate consumption commodity $subn \in N$
$P X D1_{i,subn}$	price index
$c1_{i,subn}$	share parameter
$\delta 2$	elasticity of substitution
$EUT2_i$	expenditure function

Define

$$PUT2_i := \frac{EUT2_i(\cdot)}{UT2_i}$$

as the expenditure per utility unit, we then have:

$$PUT2_i = \left[\sum_{subn} c1_{i,subn} P X D1_{i,subn}^{(1-\delta 2)} \right]^{1/(1-\delta 2)} \quad (17)$$

$$X D1_{i,subn} = c1_{i,subn} UT2_i \left[\frac{PUT2_i}{P X D1_{i,subn}} \right]^{\delta 2} \quad (18)$$

The third nest: domestic versus aggregate imported commodities

CES- utility function

$$X D1_{i,subn} = \left[c2_{i,subn} X D2_{i,subn}^{(\delta 3-1)/\delta 3} + c2b_{i,subn} X D2B_{i,subn}^{(\delta 3-1)/\delta 3} \right]^{\delta 3/(\delta 3-1)}$$

where:

$X D2_{i,subn}$	domestic goods
$X D2B_{i,subn}$	aggregate imported commodities
$P X D2B_{i,n}$	price index
$c2_{i,subn,1}, c2b_{i,subn,1}$	share parameters
$\delta 3$	elasticity of substitution
$EXD1_{i,subn}$	expenditure function
$P X D1 := EXD1 / X D1_i$	
$TT_{i,subn}$	VAT rate.

VAT is modelled as a consumption tax under the destination principle.

By now, the following equations are self explanatory.

$$PXD1_{i,subn} = \left[c2_{i,subn} \left(PG_{i,subn} (1 + TT_{i,subn}) \right)^{(1-\delta_3)} + c2b_{i,subn} PXD2_{i,subn}^{(1-\delta_3)} \right]^{1/(1-\delta_3)} \quad (19)$$

$$XD2_{i,subn} = c2_{i,subn} XD1_{i,subn} \left(\frac{PXD1_{i,subn}}{PG_{i,subn} (1 + TT_{i,subn})} \right)^{\delta_3} \quad (20)$$

$$XD2B_{i,subn} = c2b_{i,subn} XD1_{i,subn} \left(\frac{PXD1_{i,subn}}{PXD2_{i,subn}} \right)^{\delta_3} \quad (21)$$

The fourth nest: choice between imported consumption goods from different source countries.

CES-utility function:

$$XD2B_{i,subn} = \left[\sum_{ii} c3_{i,subn,ii}^{\frac{1}{\delta_4}} XD3_{i,subn,ii}^{(\delta_4-1)/\delta_4} \right]^{\delta_4/(\delta_4-1)}$$

where:

$XD3_{i,subn,ii}$	imported consumption goods
$EXD2B_{i,subn}$	expenditure function
$PXD2_{i,subn} = EXD2B_{i,subn} / XD2B_{i,subn}$	price index
$c3_{i,subn,ii}$	share parameters
δ_4	elasticity of substitution.

Note that for trade in consumption goods between ROW and EU - member states' tariffs apply and VAT is applied to producer prices including tariffs.

$$PXD2_{i,subn} = \left[\sum_{ii} c3_{i,subn,ii} \left(PG_{ii,subn} (1 + \Gamma_{i,subn,ii}) (1 + TT_{i,subn}) \right)^{(1-\delta_4)} \right]^{1/(1-\delta_4)} \quad (22)$$

$$XD3_{i,subn,ii} = c3_{i,subn,ii} XD12_{i,subn} \left(\frac{PXD12_{i,subn}}{PG_{ii,subn} (1 + \Gamma_{i,subn,ii}) (1 + TT_{i,subn})} \right)^{\delta_4} \quad (23)$$

where:

$\Gamma_{i,ii,subn}$	tariffs rates
$PXD12_{i,n}$	price index

3.3 The public sector

Consider the expenditure side of the budget first. There are two expenditure categories: lump-sum transfer payments to the representative consumer (weighted by a Laspeyres price index) and government outlays on the provision of public goods. Because firms pay for the use of the public good as an intermediate input, only net public expenditure (which is provided free of charge to the consumers) has to be financed by taxes.

Define

\bar{G} quantity of public good provided free of charge to the consumer.

On the revenue side of the budget, we have income taxes, value added taxes, tariffs and production taxes. The government budget constraint reads:

$$T_i (r KS_i + w_i (EB_i - LL_i) - A_i) +$$

(income tax revenue)

$$\begin{aligned}
& + \sum_{subn} \sum_{ii} XD1_{i,subn,ii} PG_{ii,subn} (1 + \Gamma_{i,subn,ii}) TT_{i,subn} + \\
& \text{(VAT revenue from direct consumption imports)} \\
& + \sum_{subn} \sum_{ii} XD1_{i,subn,ii} PG_{ii,subn} \Gamma_{i,subn,ii} + \\
& \text{(tariffs revenue from direct consumption imports)} \\
& + \sum_{subn} XD2_{i,subn} PG_{ii,subn} TT_{i,subn} \\
& \text{(VAT revenue from consumption of domestic goods)} \\
& + \sum_n \sum_{subn} \sum_{ii} CIX2_{i,n,subn,ii} PG_{ii,subn} \Gamma_{i,subn,ii} \\
& \text{(tariffs from importing intermediates)} \\
& + \sum_n YQ_{i,n} PG_{i,n} \frac{\tau_{i,n}}{(1 + \tau_{i,n})} + \\
& \text{(revenue from production taxes)} \\
& - TR_i QL_i - \bar{G}_i PG_{i,14} = 0 \tag{24} \\
& \text{(public expenditure)}
\end{aligned}$$

The Laspeyres price index is given by:

$$QL_i = \frac{\sum_{subn} \sum_{ii} XD3^0_{subn,ii,i} PG_{ii,subn}}{\sum_{subn} \sum_{ii} XD3^0_{subn,ii,i}} \tag{25}$$

where: $XD3^0_{subn,ii,i}$ is defined as the benchmark consumer demand (see appendix 3).

3.4 Market equilibrium condition

Labour market equilibrium

$$\sum_n LD_{i,n} - (EB_i - LL_i) = 0 \tag{26}$$

Commodity market clearing for private goods

$$XD2_{i,subn} + \sum_{ii} XD3_{ii,subn,i} + \sum_n \sum_{ii} CIX2_{ii,n,subn,i} + \sum_m CIX1_{i,m,subn} - YQ_{i,subn} = 0 \tag{27}$$

Market clearing for the public good

$$\bar{G}_i + \sum_n CIT_{i,n,14} - YQ_{i,14} = 0 \tag{28}$$

The market clearing condition on the international capital market is fulfilled by Walras' Law.

4. The complete GAMS-code

Appendices 1, 2 and 3 contain the complete GAMS-code for a CGE model. In appendices 2 and 3 we present the data set and calibrate the parameters on the production side (appendix 2) and on the consumption side (appendix 3). With the calibration procedure we determine the missing parameters once the equilibrium data set is entered and the exogenous tax rates (or tax

revenues) are given. From the equations declared in the model we can in fact obtain the values for all the distribution shares of the different functions we specified. Practically, in order to do that we first declare the parameters and then assign them values, according to the appropriate formula, by using prices equal to one and quantity equal to the equilibrium values.

Now the model is fully specified, including all parameter values obtained through calibration. Before making any counterfactual experiments, we check if, given our parameter values, the benchmark data set does indeed represent an equilibrium solution. This process is known as replication check. To proceed with the replication test we specify the model presented in the previous section within GAMS. To do this we declare the variables to be solved for, as well as equations to be used in solving the expressed variables. Appendix 1 contains the code for the model equations as well as the solution code. Part 2 of appendix 1 is identical to the system of equations reproduced in our section 2. Once all the equations we wish to solve for have been stated, we group them in GAMS using the MODEL statement, which tells the solver which equations are to be used to solve the problem (in our case we use all the equations specified). Part 3 of appendix 1 initialises the variables and specifies lower and upper bounds for the variables. For example, in order to avoid division by zero problems, we reset the lower bounds of almost all price indices to be marginally greater than zero. To help the solver find an equilibrium we pass along starting values, which are the original benchmark values.

Finally we use the SOLVE command to tell the solver:

1. to „solve“ the model we have named EUM (European Union model),
2. by using the appropriate solving routine (NLP- Non-linear programming)
3. and solve it by maximizing our objective variable.

In our model there is no real objective variable that we are trying to solve for. We do want to solve for a system of equations. In order to „fool“ the solver into thinking this was a maximization problem, we create a dummy objective variable and equation. The solver maximises this variable subject to a number of constraints, which is the system of equations we are trying to solve for.

After having replicated our benchmark equilibrium, we confirm that we obtain the same values as the benchmark and we check for: the zero profit conditions, the capital market clearing condition and the fulfillment of the budget constraints.

5. Policy experiment with the EMU model: Simulation methodology

The model is now ready to be used to perform fiscal policies simulation. Having set up the counterfactual, we solve for the equilibrium values as we did for the replication for the benchmark.

In the benchmark equilibrium all the tax rates are given exogenously. The government budget constraint is fulfilled by transfers, which are endogenously determined. It is, however, very simple to change the structure of the model in order to have some tax rates as endogenous. One should declare them as variables in the initial benchmark by changing their names (i.e. one can not have parameters and variables with the same name).

For example, we may need to have the VAT rates as endogenous in the simulation. In the program itself the VAT rates are defined as parameters and are denoted by $TTB_{i,subn}$.

If one wants to define them as variables one then has to:

- 1) introduce a new variable i.e. $TT_{i,subn}$

- 2) substitute the new variable $TT_{i,subn}$ in the system of equations instead of $TTB_{i,subn}$
 3) finally, for the replication check one can impose:

$$TT.FX(I,SUBN)=TTB(I,SUBN)$$

This statement means that $TT_{i,subn}$ are fixed at the benchmark level $TTB_{i,subn}$. In simulation 1 can free them by redefining their upper and the low level:

$$\begin{aligned} TT.LO(I,SUBN) &= 0 \\ TT.L(I,SUBN) &= TTB(I,SUBN) \\ TT.UP(I,SUBN) &= 0.9999 \end{aligned}$$

Another way to proceed is to fix the transfers to their benchmark level:

$$TRANSFER.FX(I)= TRANSFERB.FX(I)$$

and initialise $TT(I,SUBN)$ at their benchmark values :

$$TT.L(I,SUBN) = TTB(I,SUBN)$$

To give a meaningful comparison between benchmark and counterfactual cases, we need to establish a measure of gains and losses attributable to a change in parameter values. Typically one uses welfare measures, represented by the Hicksian equivalent variations. The latter take the old equilibrium incomes and prices and compute the change needed to achieve new equilibrium utilities:

$$\frac{(UT_{ex-post} - UT_{ex-ante})}{UT_{ex-ante}} * M_{ex-ante} .$$

In the dual structure the same equivalent variation would be expressed by the difference in expenditure functions :

$$e(PUT|_{ex-ante} UT_{ex-post}) - e(PUT|_{ex-ante} UT_{ex-ante}) .$$

As we have seen in section 2.2 the utility price indexes are the unit expenditure functions. Therefore, to obtain the value of the expenditure function we just have to multiply the utility level by the price index:

$$e(PUT|_{ex-ante} UT_{ex-post}) = PUT|_{ex-ante} UT_{ex-post} .$$

Given that the calibration procedure has been done using the convention that all the prices are equal to 1 including the consumer side, we can set $p_{ex-ante}$ equal to one. Hence the expression for the equivalent variation become simply:

$$UT_{ex-post} - UT_{ex-ante} .$$

Practically, just for GAMS purpose, we define as a parameter the value of the benchmark utility level after that the replication has been done. Basically UO , represents the utility level ex-ante:

$$UO(I) = UT.L(I)$$

Then we defined $U1$, as the ex-post utility level. Of course we defined them just after the simulation has been performed, as follows:

$$U1(I) = UT.L(I)$$

Hence the expression for the equivalent variations EV , is given by:

$$EV(I) = (U1(I) - UO(I))$$

To evaluate the term of trade effects we use the same methodology as described on p.136 of FRW(1995).

5.1 Equal yield experiments

We perform some simulations just to give an idea of how one can work with the model. We will begin by showing how to change the tax structure while maintaining the same level of real tax revenue. The first simulation (SIM1) represents an equal yield experiment. We keep public expenditure and transfer constant in real terms. Public expenditure is already fixed in the model while \bar{G} has been defined as parameters (see appendix 1) and are evaluated by the price of the public good. We should instead fix the transfers to their benchmark level:

$$TRANSFER.FX(I) = TRANSFERB(I)$$

The transfers are evaluated by a Laspeyres price index, which is the ratio of the sum of the initial consumption at the new price to the initial value of consumption. In this way we cope with the problem of considering the transfer fix in real terms.

The aim of this simulation is to switch to a uniform VAT rate within each European country. The ROW is also using the already uniform VAT rate to balance his government budget constraint. To perform the simulation we

- introduce a new variable such as TT1 defined just over I (over the country),
- we multiply TTB by TT1 in the system of equations, i.e. the consumer prices would look like

$$PG_{i,n}(1 + TTB_{i,subn} TT1_i)$$

- for the replication check we fix the TT1 equal to 1

$$TT1.FX(I) = 1$$

To perform the simulation one should then free the variable TT1 giving them new upper and lower bounds

$$\begin{aligned} TT1.LO(I) &= 0 \\ TT1.LO(I) &= 0.15 \\ TT1.UP(I) &= 0.999 \end{aligned}$$

and fix the TTB variable equal to 1

$$\text{TTB.FX (I,SUBN)}= 1$$

Table 1 show some of the values we obtained through simulation. It is possible anyway, to very easily display the values of all the variables declared and all the ratios or parameters definitions that we need to calculate in order to understand the results. In this case, the aim is just to give how the model functions but not about the economic interpretations of the simulations.

Table 1

Countries	Equivalent variations	% changes in the terms of trade	Uniform Vat tax rates within countries
F	1338	0.13	11.5%
BL	37	-0.09	10.1%
NL	-180	-0.46	9.8%
D	1003	0.29	9%
I	993	0.08	7%
UK	3	-0.003	7.9%
DK	-90	-0.44	18%
ROW	861	-0.09	10%

5.2 Budget incidence analysis.

In simulation SIM2 we fix all the Vat rates at 10%.

$$\text{TTB(I,SUBN)} = 0.1$$

Clearly we should have another variable vary endogenously to guarantee that the government budget constraint is fulfilled. Therefore we leave the transfers free to vary.

Table 2

Countries	Equivalent variations	% changes in the terms of trade
F	1040.72	-0.17
BL	-20.56	-0.16
NL	263.20	-0.56
D	1281.21	0.54
I	1162.25	0.53
UK	271.18	0.63
DK	-179.45	-1.74
ROW	-133.75	-0.3

6. Summary

This paper has provided an introduction to a multi-country model applied to the European Union which can be used to tackle fiscal policies questions in a static framework. We provide in addition a code written in GAMS, which accomodates the model specification in a concise and transparent framework. The effort has been put in trying to simplify the implementation of the model as much as possible by using a consistent way of specifying each single equation.

This work has been done as a part of a common project in which 5 groups are involved. In addition to providing a convenient common framework for these model-builders, this paper can also be usefull for people who wants to start exploiting the applied general equilibrium analysis to investigate fiscal policy issues.

Further work is underway in the development of the model it-self by each single group working in the network.

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Appendix N° 1- Part 1

\$TITLE: EUM
* VERSION: OCTOBER 1996
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\$OFFSYMLIST
\$ONUPELLIST
\$OFFFUELEXREF
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OPTION SYSOUT=ON;
OPTION SOLPRINT=OFF;
OPTION RESLIM=1000000;
OPTION ITERLIM=900000;
\$INCLUDE PRODLAR
\$INCLUDE CONSLAR
SCALAR
SCALEX /100000/
:
PARAMETERS
UO(I) utility level ex-ante
U1(I) utility level ex-post
EV(I) equivalent variations
CIX2O(I,N,SUBN,II)
XD3O(I,SUBN,II)
PMO(I)
PXO(I)
PM1(I)
PX1(I)
PM(I) price index for imports
PX(I) price index for exports
TOTO(I)
TOT(I) net-barter terms of trade
CON(I) total consumption + leisure demand
CHECK(I,N) zero profit conditions
CHECK1 capital market clearing condition
CHECK2(I) fulfillment of budget constraint at 2nd level
CHECK3(I,SUBN) fulfillment of budget constraint at 3rd level
CHECK4(I,SUBN) fulfillment of budget constraint at 4th level
:
POSITIVE VARIABLES
YQ(I,N) level of production
VA(I,N) value added
CIT(I,N,NN) composite intermediate products
PVA(I,N) price index for VAT
PCIT(I,N,SUBN) price index for CIT
PG(I,N) producer price of commodity n (including production taxes)
LD(I,N) labour demand
KD(I,N) capital demand
W(I) wage rate (uniform between sectors)
R rental rate of K (uniform between countries)
CIX1(I,N,SUBN) domestically produced intermediates
CIX1B(I,N,SUBN) imported composite intermediates
PCIX1B(I,N,SUBN) price for CIX1B
CIX2(I,N,SUBN,II) imported intermediates inputs
* CONSUMPTION SIDE
UT(I) top utility level
PUT1(I) price index
UT2(I) second utility level
LL(I) leisure demand

PUT2(I) price index for 2nd utility level
 XD1(I,SUBN) aggregate consumption commodity
 PXD1(I,SUBN) price for XD1
 XD2(I,SUBN) domestic goods
 XD2B(I,SUBN) aggregate imported commodities
 PXD2B(I,SUBN) price index for XD2B
 XD3(I,SUBN,II) imported consumption goods
 * GOVERNMENT SIDE
 TRANSFER(I) transfer
 TT1(I) uniform VAT tax rate
 QL(I) Laspeyres price index
 VARIABLES
 DUMMY dummy objective variable

Appendix N° 1- Part 2

EQUATIONS

* PRODUCTION SIDE

LDEQUAT(I,N) labour demand
 KDEQUAT(I,N) capital demand
 PVAEQUAT(I,N) price of value added
 VAEQUAT(I,N) value added
 CITEQUAT(I,N,NN) total intermediate inputs
 PGEQUAT(I,N) producer prices
 CIX1EQUAT(I,N,SUBN) national intermediate inputs
 CIX1BEQUAT(I,N,SUBN) total imported " "
 PCITEQUAT(I,N,SUBN) price index of CIT
 CIX2EQUAT(I,N,SUBN,II) imported intermediate inputs
 PCIX1EQUAT(I,N,SUBN) price index of CIX1
 GOVBUDGET(I) government budget constraint
 PUBGOOMKT(I) equilibrium on the public good mkt

* CONSUMER SIDE

BUDGCONS(I) consumer budget constraint
 INCOMDEF(I)
 XD1EQUAT(I,N) total consumption demand
 LLEQUAT(I) leisure demand
 PUT1EQUAT(I) price index of UT1
 UT2EQUAT(I) second utility level
 PUT2EQUAT(I) price index of UT2
 PXD1EQUAT(I,SUBN) price index of XD1
 XD2EQUAT(I,SUBN) demand of national goods
 XD2BEQUAT(I,SUBN) demand for the composite imported goods
 PXD2BEQUAT(I,SUBN) price index of XD2
 XD3EQUAT(I,SUBN,I) demand for imported goods
 QLEQUAT(I) Laspeyres price index

* EQUILIBRIUM CONDITIONS

EXMKTG(I,SUBN) excess demand on good markets
 EXMKT(L) excess demand on L markets
 *EXMKT(K)
 DUMOBJ dummy

:

* PRODUCTION SIDE

* Value added demand - equation number (1)

VAEQUAT(I,N)\$(A1(I,N) NE 0)..

VA(I,N) =E= AO(I,N)*YQ(I,N)

:

* Demand of composite intermediate inputs (national + imported)

* equation number (2)

CITEQUAT(I,N,NN)\$(A1(I,N) NE 0 and CITB(I,N,NN) NE 0)..

CIT(I,N,NN) =E= AOCI(I,N,NN)*YQ(I,N)

```

:
* Producer price - equation number (3)
PGEQUAT(I,N)$(A1(I,N) NE 0)..
PG(I,N) =E= ( AO(I,N)*PVA(I,N)
+ SUM(SUBN,AOCI(I,N,SUBN)*PCIT(I,N,SUBN))
+ AOCI(I,N,"14")*PG(I,"14"))*(1+TPB(I,N))
:
* Value added Unit cost function - equation number (4)
PVAEQUAT(I,N)$(A1(I,N) NE 0)..
PVA(I,N) =E= (DEL2(I,N)*W(I)**(1-SIGMA2(I,N))
+ (1-DEL2(I,N))*R**(1-SIGMA2(I,N)))*(1/(1-SIGMA2(I,N)))
:
* Labour demand: CES function - equation number (5)
LDEQUAT(I,N)$(A1(I,N) NE 0)..
LD(I,N) =E= DEL2(I,N) * VA(I,N)* (PVA(I,N)/W(I))**SIGMA2(I,N)
:
* Capital demand: CES function - equation number (6)
KDEQUAT(I,N)$(A1(I,N) NE 0)..
KD(I,N) =E= (1-DEL2(I,N)) * VA(I,N)* (PVA(I,N)/R)**SIGMA2(I,N)
:
* price index of CIT - equation number (7)
PCITEQUAT(I,N,SUBN)$(A1(I,N) NE 0 and CITB(I,N,SUBN) NE 0)..
PCIT(I,N,SUBN) =E= ( AOCIX(I,N,SUBN)*PG(I,SUBN)**(1-SIGMA3(I,N,SUBN))
+ (1-AOCIX(I,N,SUBN))*PCIX1B(I,N,SUBN)
** (1-SIGMA3(I,N,SUBN)))*(1/(1-SIGMA3(I,N,SUBN)))
:
* Demand of national inputs - equation number (8)
CIX1EQUAT(I,N,SUBN)$(CIXB(I,SUBN,I,N) NE 0)..
CIX1(I,N,SUBN) =E= AOCIX(I,N,SUBN)*CIT(I,N,SUBN)
*(PCIT(I,N,SUBN)/PG(I,SUBN))**SIGMA3(I,N,SUBN)
:
* Demand of composite imported inputs - equation number (9)
CIX1BEQUAT(I,N,SUBN)$(sum(II$(ORD(II) NE ORD(I)),CIXB(II,SUBN,I,N)) NE 0)..
CIX1B(I,N,SUBN) =E= (1-AOCIX(I,N,SUBN))*CIT(I,N,SUBN)
*(PCIT(I,N,SUBN)/PCIX1B(I,N,SUBN))**SIGMA3(I,N,SUBN)
:
* equation number (10)
PCIX1EQUAT(I,N,SUBN)$(sum(II$(ORD(II) NE ORD(I)),CIXB(II,SUBN,I,N)) NE 0)..
PCIX1B(I,N,SUBN) =E= (SUM(II$(ORD(I) NE ORD(II)),
AOCIX2(I,N,SUBN,II)*(PG(II,SUBN)*(1+TARPB(I,SUBN,II)
))** (1-SIGMA4(I,SUBN,N)))* (1/(1-SIGMA4(I,SUBN,N)))
:
* Demand of imported inputs - equation number (11)
CIX2EQUAT(I,N,SUBN,II)$(CIXB(II,SUBN,I,N) NE 0)..
CIX2(I,N,SUBN,II) =E= AOCIX2(I,N,SUBN,II)*CIX1B(I,N,SUBN)
*(PCIX1B(I,N,SUBN)/PG(II,SUBN)*(1+TARPB(I,SUBN,II)
))**SIGMA4(I,SUBN,N)
:
* CONSUMER SIDE
* index price - equation number (12)
PUT1EQUAT(I)..
PUT1(I) =E= ( (CL(I))*(W(I)*(1-INCTAXRB(I)))*(1-DELTA1(I))
+ CC(I)*PUT2(I)**(1-DELTA1(I)))*(1/(1-DELTA1(I)))
:
* income definition - equation number (13)
INCOMDEF(I)..
UT(I)*PUT1(I) =E= (R*KSB(I) + W(I)*EB(I))*(1-INCTAXRB(I)) +
ALLOWB(I)*INCTAXRB(I) + TRANSFER(I)*QL(I)
:

```

```

* consumer budget constraint - equation number (14)
BUDGCONS(I)..
UT(I)*PUT1(I) =E= UT2(I)*PUT2(I) + LL(I)*W(I)*(1-INCTAXRB(I))
:
* leisure demand - equation number (15)
LLEQUAT(I)..
LL(I) =E= CL(I)*UT(I)
      *(PUT1(I)/(W(I)*(1-INCTAXRB(I))))**DELTA1(I)
:
* aggregate consumption - equation number (16)
UT2EQUAT(I)..
UT2(I) =E= CC(I)*UT(I)
      *(PUT1(I)/PUT2(I))**DELTA1(I)
:
* price index - equation number (17)
PUT2EQUAT(I)..
PUT2(I) =E= (SUM(SUBN,
      C1(I,SUBN)*PXD1(I,SUBN)**(1-DELTA2(I))))*(1/(1-DELTA2(I)))
:
* aggregation of comparable imported and domestic consumption -
* equation number (18)
XD1EQUAT(I,SUBN)$(A1(I,SUBN) NE 0)..
XD1(I,SUBN) =E= C1(I,SUBN)*UT2(I)*(PUT2(I)/PXD1(I,SUBN))**DELTA2(I)
:
* price index - equation number (19)
PXD1EQUAT(I,SUBN)$(A1(I,SUBN) NE 0)..
PXD1(I,SUBN) =E= (C2(I,SUBN)*(PG(I,SUBN)*(1+TTB(I,SUBN)*TT1(I))
      )**(1-DELTA3(I,SUBN))
      + C2B(I,SUBN)*PXD2B(I,SUBN)**(1-DELTA3(I,SUBN))
      )**(1/(1-DELTA3(I,SUBN))))
:
* demand for domestic consumption goods - equation number (20)
XD2EQUAT(I,SUBN)$(A1(I,SUBN) NE 0)..
XD2(I,SUBN) =E= C2(I,SUBN)*XD1(I,SUBN)
      *(PXD1(I,SUBN)/(PG(I,SUBN)*(1+TTB(I,SUBN)*TT1(I))
      )**DELTA3(I,SUBN))
:
* demand for a composite imported commodity - equation number (21)
XD2BEQUAT(I,SUBN)$(A1(I,SUBN) NE 0)..
XD2B(I,SUBN) =E= C2B(I,SUBN)*XD1(I,SUBN)
      *(PXD1(I,SUBN)/PXD2B(I,SUBN))**DELTA3(I,SUBN)
:
* price index - equation number (22)
PXD2BEQUAT(I,SUBN)$(A1(I,SUBN) NE 0)..
PXD2B(I,SUBN) =E= (SUM(II$(ORD(I) NE ORD(II)),
      C3(I,SUBN,II)*(PG(II,SUBN)
      *(1+TARB(I,SUBN,II))*(1+TTB(I,SUBN)*TT1(I))
      )**(1-DELTA4(I,SUBN))))
      )**(1/(1-DELTA4(I,SUBN)))
:
* demand for comparable imported consumption goods
* equation number (23)
XD3EQUAT(I,SUBN,II)$(ORD(I) NE ORD(II) and A3(SUBN,II,I) NE 0)..
XD3(I,SUBN,II) =E= C3(I,SUBN,II)*XD2B(I,SUBN)
      *(PXD2B(I,SUBN)
      /(PG(II,SUBN)*(1+TARB(I,SUBN,II))
      *(1+TTB(I,SUBN)*TT1(I))))**DELTA4(I,SUBN)
:
* MARKET CLEARING EQUATIONS

```

```

* government budget constraint - equation number (24)
GOVBUDGET(I)..
  INCTAXRB(I)*(R*KSB(I) + W(I)*(EB(I)-LL(I)) - ALLOWB(I))
    + SUM(SUBN,SUM(II$(ORD(I) NE ORD(II)),
      XD3(I,SUBN,II)*PG(II,SUBN)
      *(1+TARB(I,SUBN,II))*TTB(I,SUBN)*TT1(I)))
    + SUM(SUBN,SUM(II$(TARB(I,SUBN,II) NE 0),
      XD3(I,SUBN,II)*PG(II,SUBN)*TARB(I,SUBN,II)))
    + SUM(SUBN,XD2(I,SUBN)*PG(I,SUBN)*TTB(I,SUBN)*TT1(I))
    + SUM(N,SUM(SUBN,SUM(II$(ORD(I) NE ORD(II)),
      CIX2(I,N,SUBN,II)*PG(II,SUBN)*TARPB(I,SUBN,II))))
    + SUM(N,YQ(I,N)*PG(I,N)*(TPB(I,N)/(1+TPB(I,N))))
    =E= TRANSFER(I)*QL(I) + PUBEXPB(I)*PG(I,"14")
;
* Laspeyres price index - equation number (25)
QLEQUAT(I)..
  QL(I) =E= SUM(SUBN,SUM(II,A3(SUBN,II,I)*PG(II,SUBN)))/
    SUM(SUBN,SUM(II,A3(SUBN,II,I)))
;
*Labour market - equation number (26)
EXMKTL(I)..
SUM(N,LD(I,N)) - (EB(I)-LL(I)) =E= 0
;
* Market clearing condition - equation number (27)
EXMKTG(I,SUBN)$(A1(I,SUBN) NE 0)..
  XD2(I,SUBN) + SUM(II$(ORD(II) NE ORD(I)),XD3(II,SUBN,I))
  + SUM(N,SUM(II$(ORD(II) NE ORD(I)),CIX2(II,N,SUBN,I)))
  + SUM(NN,CIX1(I,NN,SUBN)) - YQ(I,SUBN) =E= 0
;
* public good clearing condition - equation number (28)
PUBGOOMKT(I)..
  PUBEXPB(I) + SUM(N,CIT(I,N,"14")) - YQ(I,"14") =E= 0
;
*Capital market - equation number (29)
*EXMKTK..
*SUM(N,SUM(I,KD(I,N))) - SUM(I,KSB(I)) =E= 0
*
* The dummy objective function
DUMOBJ..
  DUMMY =E= 0
;
MODEL EUM /ALL/;

```

Appendix N° 1- Part 3

```

DUMMY.L      = 0;

YQ.L(I,N)    = A1(I,N);
YQ.SCALE(I,N) = SCALEX;
YQ.FX(I,N)$(A1(I,N) EQ 0) = 0;
YQ.LO(I,N)   = 0;

PG.L(I,N)    = 1;
PG.LO(I,N)   = 0.000001;
PG.FX(I,N)$(A1(I,N) EQ 0) = 0;

R.LO = 0.0001;
R.L = 1;

```

W.LO(I) = 0.00001;

W.L(I) = 1;

W.FX("FF")=1;

VA.L(I,N) = (A2(I,N) + KDB(I,N));

VA.SCALE(I,N) = SCALEX;

VA.FX(I,N)\$(A1(I,N) eq 0) = 0;

LD.L(I,N) = A2(I,N);

LD.SCALE(I,N) = SCALEX;

LD.FX(I,N)\$(A1(I,N) eq 0) = 0;

KD.L(I,N) = KDB(I,N);

KD.SCALE(I,N) = SCALEX;

KD.FX(I,N)\$(A1(I,N) eq 0) = 0;

PVA.L(I,N) = 1;

CIT.L(I,N,NN) = CITB(I,N,NN);

CIT.SCALE(I,N,NN) = SCALEX;

CIT.FX(I,N,NN)\$(A1(I,N) EQ 0) = 0;

CIT.FX(I,N,NN)\$(CITB(I,N,NN) EQ 0) = 0;

PCIT.L(I,N,SUBN) = 1;

PCIT.LO(I,N,SUBN) = 0.0000001;

PCIT.FX(I,N,SUBN)\$(A1(I,N) EQ 0) = 0;

PCIT.FX(I,N,SUBN)\$(CITB(I,N,SUBN) EQ 0) = 0;

CIX1.L(I,N,SUBN) = CIXB(I,SUBN,I,N);

CIX1.SCALE(I,N,SUBN) = SCALEX;

CIX1.FX(I,N,SUBN)\$(CIXB(I,SUBN,I,N) EQ 0) = 0;

CIX1B.L(I,N,SUBN) = CITB(I,N,SUBN) - CIXB(I,SUBN,I,N);

CIX1B.SCALE(I,N,SUBN) = SCALEX;

CIX1B.FX(I,N,SUBN)\$(SUM(II\$(ORD(II) NE ORD(I)),

CIXB(II,SUBN,I,N)) EQ 0) = 0;

PCIX1B.LO(I,N,SUBN) = 0.0000000001;

PCIX1B.L(I,N,SUBN) = 1;

PCIX1B.FX(I,N,SUBN)\$(SUM(II\$(ORD(II) NE ORD(I)),

CIXB(II,SUBN,I,N)) EQ 0) = 0;

CIX2.L(I,N,SUBN,II) = CIXB(II,SUBN,I,N);

CIX2.SCALE(I,N,SUBN,II) = SCALEX;

CIX2.FX(I,N,SUBN,II)\$(CIXB(II,SUBN,I,N) EQ 0) = 0;

CIX2.FX(I,N,SUBN,I) = 0;

TT1.FX(I) = 1;

UT.L(I) = FULLDISP(I);

UT.SCALE(I) = SCALEX;

LL.L(I) = LLB(I);

LL.SCALE(I) = SCALEX;

PUT1.LO(I) = 0.000001;

PUT1.L(I) = 1;

PUT2.LO(I) = 0.0000001;

PUT2.L(I) = 1;

UT2.L(I) = SUM(SUBN.A5(I,SUBN));

UT2.SCALE(I) = SCALEX;

XD1.L(I,SUBN) = A5(I,SUBN);

XD1.SCALE(I,SUBN) = SCALEX;

XD1.FX(I,SUBN)\$(A5(I,SUBN) EQ 0) = 0;

PXD1.L(I,SUBN) = 1;

PXD1.LO(I,SUBN) = 0.000000001;

PXD1.FX(I,SUBN)\$(A5(I,SUBN) EQ 0) = 0;

XD2.L(I,SUBN) = A3(SUBN,I,I);

XD2.SCALE(I,SUBN) = SCALEX;

XD2.FX(I,SUBN)\$(A3(SUBN,I,I) EQ 0) = 0;

XD2B.L(I,SUBN) = SUM(II\$(ORD(II) NE ORD(I)),

A3(SUBN,II,I)*(1+TARB(I,SUBN,II))*(1+TTB(I,SUBN)*TT1.L(I)));

XD2B.SCALE(I,SUBN) = SCALEX;

XD2B.FX(I,SUBN)\$(SUM(II\$(ORD(II) NE ORD(I)),

A3(SUBN,II,I)*(1+TARB(I,SUBN,II))*(1+TTB(I,SUBN)*TT1.L(I))) EQ 0) = 0;

PXD2B.L(I,SUBN) = 1;

PXD2B.LO(I,SUBN) = 0.000000001;

PXD2B.FX(I,SUBN)\$(SUM(II\$(ORD(II) NE ORD(I)),

A3(SUBN,II,I)*(1+TARB(I,SUBN,II))*(1+TTB(I,SUBN)*TT1.L(I))) EQ 0) = 0;

XD3.L(I,SUBN,II) = A3(SUBN,II,I);

XD3.SCALE(I,SUBN,II) = SCALEX;

XD3.FX(I,SUBN,II)\$(ORD(I) EQ ORD(II)) = 0;

XD3.FX(I,SUBN,II)\$(A3(SUBN,II,I) EQ 0) = 0;

*TRANSFER.FX(I) = TRANSFERB(I);

TRANSFER.SCALE(I) = SCALEX;

TRANSFER.L(I) = TRANSFERB(I);

QL.L(I) = 1;

QL.LO(I) = 0.001;

LDEQUAT.SCALE(I,N) = SCALEX;

KDEQUAT.SCALE(I,N) = SCALEX;

VAEQUAT.SCALE(I,N) = SCALEX;

CITEQUAT.SCALE(I,N,NN) = SCALEX;

CIX1EQUAT.SCALE(I,N,SUBN) = SCALEX;

CIX1BEQUAT.SCALE(I,N,SUBN) = SCALEX;

CIX2EQUAT.SCALE(I,N,SUBN,II) = SCALEX;

GOVBUDGET.SCALE(I) = SCALEX;

PUBGOOMKT.SCALE(I) = SCALEX;

INCOMDEF.SCALE(I) = SCALEX;

BUDGCONS.SCALE(I) = SCALEX;

XD1EQUAT.SCALE(I,N) = SCALEX;

LLEQUAT.SCALE(I) = SCALEX;

UT2EQUAT.SCALE(I) = SCALEX;

XD2EQUAT.SCALE(I,SUBN) = SCALEX;

XD2BEQUAT.SCALE(I,SUBN) = SCALEX;

XD3EQUAT.SCALE(I,SUBN,II) = SCALEX;

```

EXMKTG.SCALE(I,SUBN)          = SCALEX;
*EXMKTL.SCALE(I)              = SCALEX;
DUMOBJ.SCALE                   = SCALEX;

```

```

EUM.HOLDFIXED = 1;
EUM.WORKSPACE = 18;
EUM.SCALEOPT = 1;

```

```

SOLVE EUM USING NLP MINIMIZING DUMMY;

```

```

UO(I) = UT.L(I);
MO(I) = UT.L(I)*PUT1.L(I);
CIX2O(I,N,SUBN,II) = CIX2.L(I,N,SUBN,II);
XD3O(I,SUBN,II) = XD3.L(I,SUBN,II);
PMO(I) = SUM(N,SUM(SUBN,SUM(II,CIX2O(I,N,SUBN,II)*PG.L(II,SUBN)))) +
SUM(II,SUM(SUBN,XD3O(I,SUBN,II)*PG.L(II,SUBN)));
PXO(I) = SUM(II,SUM(SUBN,XD3O(II,SUBN,I)*PG.L(I,SUBN))) +
SUM(II,SUM(N,SUM(SUBN,CIX2O(II,N,SUBN,I)*PG.L(I,SUBN))));
TOTO(I) = PMO(I)/PXO(I);
CHECK(I,N) = YQ.L(I,N)*PG.L(I,N) -
(SUM(SUBN,CIT.L(I,N,SUBN)*PCIT.L(I,N,SUBN))
+ CIT.L(I,N,"14")*PG.L(I,"14")
+ VA.L(I,N)*PVA.L(I,N))*(1+TPB(I,N))
:
CHECK1 = SUM(N,SUM(I,KD.L(I,N))) - SUM(I,KSB(I))
:
CHECK2(I) = UT2.L(I)*PUT2.L(I) - SUM(SUBN,XD1.L(I,SUBN)*PXD1.L(I,SUBN))
:
CHECK3(I,SUBN) = XD1.L(I,SUBN)*PXD1.L(I,SUBN) -
(XD2.L(I,SUBN)*PG.L(I,SUBN)*(1+TTB(I,SUBN)*TT1.L(I))
+ XD2B.L(I,SUBN)*PXD2B.L(I,SUBN))
:
CHECK4(I,SUBN) = XD2B.L(I,SUBN)*PXD2B.L(I,SUBN) -
SUM(II,XD3.L(I,SUBN,II)*PG.L(II,SUBN)
*(1+TARB(I,SUBN,II))*(1+TTB(I,SUBN)*TT1.L(I)))
:
DISPLAY
YQ.L, PG.L, W.L, PVA.L, PCIT.L, PXD1.L, XD2B.L;

```

Appendix N° 2

SET

I different regions

/FF France
BL Belgium & Luxembourg
NL Netherlands
DD Germany
II Italy
UK United Kingdom & Ireland
DK Denmark
ROW Rest of the world/

N number of sectors

/1*14/

SUBN(N)

/1*13/

;

ALIAS(I,II,III)

;

ALIAS(N,NN)

;

ALIAS(SUBN,SUBNN)

;

* * * * *

* PRODUCTION SIDE *

* * * * *

SCALAR

SCALE /1/

* scaling is very important in order to get good results and fast execution. In general there are 2 ways of scaling:

* 1) implicit scaling: all numbers are roughly scaled to 1 inside the model

* 2) explicit scaling: use of natural units in the model and scaling being done by the modelname.scaleopt =1 (see GAMS

* Conopt Appendix);

* Note: in this case SCALE /1/ and in the file large

* modelname.scalect = 1 so the program is running using the explicit scaling.

* You can try to scale the model using different values in order to obtain as results the % variations.

;
 TABLE A1(I,N) Level of production

	1	2	3	4	5	6	7
FF	31193	45243	6167	11874	6099	2604	4930
BL	3120	1719	1326	393	850	127	480
NL	6970	22885	2926	1625	1187	259	2645
DD	10704	18748	9836	7325	12482	4046	9530
II	26689	15382	4488	5365	8257	1807	4074
UK	8029	35400	5464	3728	5687	1411	3816
DK	3608	2197	550	604	1147	151	410
ROW	107622	322645	42757	41599	40063	22109	55101

;
 PARAMETER
 A1(I,N)
 ;
 A1(I,N)= A1(I,N)*SCALE
 ;

TABLE A2(I,N) Labour demand

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FF	2891	17409	5684	8938	6214	2144	6403	8651	3226	5733	5681	8618	104781	48214
BL	120	4280	1399	1271	1424	72	1742	540	452	1527	1710	2359	19470	10246
NL	958	2854	1835	1525	1385	193	2204	407	824	2658	877	3219	44589	12537
DD	2748	24249	11637	13881	19290	4653	17530	14289	2937	9767	7939	18878	148305	59388
II	4420	11692	4413	5260	3411	660	4863	3862	1936	5039	9425	9776	69148	37454
UK	3390	18220	5255	7539	10973	1893	8001	5970	5074	7202	6840	13914	122069	58035
DK	484	755	428	560	1051	160	441	0	405	1297	398	1479	14627	7866
ROW	32207	170585	67124	100448	112517	33317	141515	74224	60117	81048	54460	206346	1854021	1236014

;
 PARAMETER
 A2(I,N)
 ;
 A2(I,N)= A2(I,N)*SCALE
 ;

TABLE KDB(I,N) capital services demand

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FF	31193	45243	6167	11874	6099	2604	4930	8155	2138	16049	6018	13280	243164	8811
BL	3120	1719	1326	393	850	127	480	237	112	1371	1020	979	25945	2020
NL	6970	22885	2926	1625	1187	259	2645	845	520	7278	1209	4708	60154	35
DD	10704	18748	9836	7325	12482	4046	9530	9738	1181	8058	3745	12267	129660	3286
II	26689	15382	4488	5365	8257	1807	4074	3050	1115	7532	12637	13558	138509	3432
UK	8029	35400	5464	3728	5687	1411	3816	2036	1850	8660	3426	9186	67561	2246
DK	3608	2197	550	604	1147	151	410	0	376	1901	528	1605	15585	677
ROW	107622	322645	42757	41599	40063	22109	55101	23174	8488	67895	14401	92852	1610137	33703

;

PARAMETER

KDB(I,N)

;

KDB(I,N)= KDB(I,N)*SCALE

;

TABLE CIXB(I,N,I,N) imported and national intermediate inputs

* For obvious reasons we do print-out only the first page of this table.

	FF.1	FF.2	FF.3	FF.4	FF.5	FF.6	FF.7	FF.8	FF.9	FF.10	FF.11	FF.12	FF.13	FF.14
FF.1	10468	43	135	0	0	0	0	0	0	37502	725	2633	1800	294
FF.2	2435	24572	3666	6437	2677	638	2287	3135	1421	1746	708	2491	28160	4584
FF.3	4114	1271	5794	795	299	39	957	406	215	261	1159	2561	2882	812
FF.4	61	862	642	3358	2966	311	2570	3555	1836	751	384	756	2881	1765
FF.5	1167	666	70	411	1386	0	75	572	416	128	157	263	1290	1189
FF.6	0	3	0	19	0	92	61	17	114	0	0	0	290	113
FF.7	14	613	65	445	805	805	1483	328	853	12	0	67	3160	1290
FF.8	0	0	0	0	0	0	0	2491	104	0	0	0	4659	1471
FF.9	78	0	0	0	0	0	0	389	2799	0	0	34	2444	2986
FF.10	6969	14	573	0	0	0	0	0	0	5121	82	12	9753	1329
FF.11	253	56	128	44	53	61	118	363	193	14	10522	722	1727	193
FF.12	316	1111	1850	585	381	367	800	1155	392	2734	980	9991	15819	2792

FF.13	4454	13585	4756	2932	2686	1706	3181	3210	2026	6683	3176	8089	83681	27034
FF.14	387	715	198	90	113	0	65	65	357	427	99	251	3862	14160
BL.1	176	0	0	0	0	0	0	0	0	215	63	9	23	0
BL.2	33	1068	49	98	96	0	37	65	12	7	2	30	323	49
BL.3	171	7	545	12	2	0	16	12	0	12	112	220	44	0
BL.4	2	2	7	61	47	0	9	5	5	7	9	21	16	14
BL.5	7	9	2	2	177	0	0	2	7	2	7	14	77	2
BL.6	0	0	0	0	0	13	0	0	0	0	0	0	0	0
BL.7	0	2	0	2	5	2	286	0	5	0	0	2	35	12
BL.8	0	0	0	0	0	0	0	329	0	0	0	0	21	0
BL.9	0	0	0	0	0	0	0	0	43	0	0	0	5	2
BL.10	33	0	16	0	0	0	0	0	0	662	23	0	70	0
BL.11	9	0	0	0	0	0	0	0	0	0	758	0	23	0
BL.12	2	12	26	7	14	0	9	33	2	58	9	436	302	56
BL.13	0	59	138	7	0	0	52	0	20	0	98	7	2110	52
BL.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NL.1	54	0	0	0	0	0	0	0	0	271	12	5	12	0
NL.2	44	1088	95	69	79	2	32	19	25	9	2	30	276	42
NL.3	190	19	575	16	2	0	35	7	2	14	51	169	65	0
NL.4	2	0	2	21	9	0	2	2	9	5	0	7	12	7
NL.5	2	2	0	5	62	0	0	2	23	0	2	9	39	0
NL.6	0	0	0	0	0	32	2	0	0	0	0	0	0	0
NL.7	0	7	0	7	5	2	203	2	16	0	0	19	58	16
NL.8	0	0	0	0	0	0	0	49	0	0	0	0	12	0
NL.9	0	0	0	0	0	0	0	2	114	0	0	0	9	7
NL.10	44	0	16	0	0	0	0	0	0	650	30	2	35	0
NL.11	5	0	0	0	0	0	0	0	0	0	101	0	5	0
NL.12	2	2	5	2	2	0	2	5	2	23	2	167	86	16
NL.13	0	15	73	3	0	0	36	0	61	0	30	3	1674	46
NL.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DD.1	26	0	0	0	0	0	0	0	0	36	16	5	21	0
DD.2	73	2238	93	688	275	29	166	324	36	16	3	91	548	80
DD.3	117	13	1114	42	8	0	52	55	0	8	208	540	177	0
DD.4	18	5	34	255	197	3	73	106	34	18	42	88	112	86

```

;
PARAMETER
CIXB(I,N,I,N)
TARPB(I,N,I) tariffs on intermediates
;
CIXB(I,N,II,NN)= CIXB(I,N,II,NN)*SCALE
;
TARPB(I,"1","ROW")= 02;
TARPB(I,"2","ROW")= 02;
TARPB(I,"3","ROW")= 07;
TARPB(I,"4","ROW")= 05;
TARPB(I,"5","ROW")= 05;
TARPB(I,"6","ROW")= 06;
TARPB(I,"7","ROW")= 08;
TARPB(I,"8","ROW")= 06;
TARPB(I,"9","ROW")= 06;
TARPB(I,"10","ROW")= 04;
TARPB(I,"11","ROW")= 09;
TARPB(I,"12","ROW")= 04;
TARPB("ROW","1",I)= 05;
TARPB("ROW","2",I)= 02;
TARPB("ROW","3",I)= 05;
TARPB("ROW","4",I)= 04;
TARPB("ROW","5",I)= 03;
TARPB("ROW","6",I)= 05;
TARPB("ROW","7",I)= 04;
TARPB("ROW","8",I)= 02;
TARPB("ROW","9",I)= 02;
TARPB("ROW","10",I)= 0.2;
TARPB("ROW","11",I)= 0.12;
TARPB("ROW","12",I)= 03;
TARPB("ROW",N,"ROW")= 0;

```

TABLE PRODTAXES(I,N) production taxes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FF	1030,78	4034,48	2532,14	57508	2980,87	1063,6	3684,7	4322,36	538,57	12717,7	3852,98	5594,14	59999,3	1,39

BL	-251,6	1420,18	-110,46	-27,39	-49,72	-3,98	-44,24	-52,29	-33,6	845,63	-88,59	-83,48	-954,46	0,35
NL	164,67	1608,89	-261	-18,7	-34,17	-7,86	-84,68	0,75	-185,69	-267,31	-83,26	-56,3	357,65	4
DD	-442,59	10515,5	407,94	3212	4687	220,98	39,82	4199	-121,23	7094,91	71,89	245,56	5251,36	0,36
II	-14954	9490,5	43,26	-56,24	-61,52	-124,75	-10,29	-9,64	-213,25	2055,57	-175,21	-212,98	-17518	0,46
UK	-10808	8673,31	1704	370,41	494,86	56,96	232,41	1821,26	-671	12596,9	99,54	658,24	15411,9	0,3
DK	-219	792,61	21,18	-5,33	-3,42	-2,16	18,13	0	201,4	856,86	-30,94	-26,64	628,53	-0,21
ROW	6332,68	78930,4	6088,8	7571,37	5269,47	1609,23	7692,26	10391,7	1381,85	41758,6	2033,6	10707,9	411222	0,42

;

PARAMETER

PRODTAXES(I,N)

SIGMA2(I,N) elas. of subs. between K and L

SIGMA3(I,N,SUBN) elas. of subs. between imported and domestic

* intermediates

SIGMA4(II,NN,N) elas. of subs. within imported intermediates

* they all can be transformed in table to have elas.

* sector and country specific

AOCIX2(I,N,N,I)

CITB(I,N,N) composite intermediate inputs

DEL2(I,N) share parameter between composite K and L

AO(I,N) share of the VA over the total production

AOCI(I,N,N) share of the composite intermediate inputs

AOCIX(I,N,N) share of the national and imported inputs

AOCIX2(I,N,N,I)

TPB(I,N) production tax rates

;

PRODTAXES(I,N) = PRODTAXES(I,N)*SCALE

;

SIGMA2(I,N) = 0.5

;

SIGMA3(I,N,SUBN) = 0.5

;

SIGMA4(II,NN,N) = 0.5

;

* total value of the intermediate consumption

* of type NN for sector N in country I

CITB(I,N,NN) = SUM(II,CIXB(II,NN,I,N))*(1+TARPB(I,NN,II)))

```

;
DEL2(I,N)$(A2(I,N) NE 0) = A2(I,N)/(A2(I,N) + KDB(I,N))
;
AO(I,N)$(A1(I,N) NE 0) = (A2(I,N) + KDB(I,N))/A1(I,N)
;
AOCI(I,N,NN)$(A1(I,N) NE 0) = CITB(I,N,NN)/A1(I,N)
;
AOCIX(I,N,NN)$(CITB(I,N,NN) NE 0) = CIXB(I,NN,I,N)*(1+TARPB(I,NN,I))/CITB(I,N,NN)
;
AOCIX2(I,N,NN,II)$(ORD(II) NE ORD(I) and CITB(I,N,NN) NE CIXB(I,NN,I,N))
= (CIXB(II,NN,I,N)*(1+TARPB(I,NN,II)**SIGMA4(I,NN,N))
/(CITB(I,N,NN) - CIXB(I,NN,I,N))
;
TPB(I,N)$(A1(I,N) NE 0) = PRODTAXES(I,N)/(A1(I,N)-PRODTAXES(I,N))
;
DISPLAY
CITB,DEL2,AO,AOCI,AOCIX,AOCIX2

```

Appendix N° 3

* CONSUMER SIDE *

TABLE A3(SUBN.I.I) consumer demand

	FF	BL	NL	DD	II	UK	DK	ROW
1,FF	9922	85	29	195	57	47	3	232
2,FF	38990	86	56	390	62	53	15	324
3,FF	9819	33	26	55	59	10	3	334
4,FF	17313	98	27	113	76	40	3	102
5,FF	16560	121	61	212	186	82	8	1478
6,FF	8111	56	55	237	127	83	5	517
7,FF	16231	80	65	242	122	43	4	754
8,FF	20986	234	330	728	629	125	0	2058
9,FF	6164	17	17	37	20	50	11	1399
10,FF	64299	238	150	675	604	205	13	1153
11,FF	20890	251	96	414	103	52	8	718
12,FF	17749	125	62	199	49	31	4	710
13,FF	394894	454	98	201	25	323	8	9339
1,BL	137	1297	37	120	4	12	0	25
2,BL	89	3269	115	334	12	37	25	223
3,BL	100	1334	76	109	51	19	6	117
4,BL	54	979	51	41	9	15	0	11
5,BL	162	2189	72	89	70	50	6	484
6,BL	13	440	5	9	4	8	0	63
7,BL	233	2280	249	136	66	31	5	136
8,BL	234	1924	373	612	87	80	0	344
9,BL	22	681	43	9	2	12	13	108
10,BL	518	7495	352	454	128	134	9	138
11,BL	424	2861	322	429	36	80	10	236
12,BL	228	2082	144	159	22	23	3	370
13,BL	328	42782	72	73	1	68	4	1493
1,NL	25	17	796	186	2	9	1	61
2,NL	181	340	11692	1270	38	69	67	146
3,NL	20	27	971	39	14	4	1	194
4,NL	16	40	1466	37	5	11	1	15
5,NL	50	66	2829	92	19	27	4	272
6,NL	33	15	785	41	18	16	1	108
7,NL	135	165	3925	290	64	44	11	437
8,NL	48	44	3199	59	22	13	0	87
9,NL	51	21	2160	44	3	41	21	459
10,NL	438	311	15380	1525	305	249	17	672
11,NL	59	180	4176	282	9	20	6	157
12,NL	81	168	4253	236	9	20	5	189
13,NL	207	230	100648	120	1	273	4	2089
1,DD	8	7	5	4628	6	7	1	74
2,DD	134	84	138	24290	27	37	31	454
3,DD	12	9	10	2265	12	3	2	798
4,DD	78	48	64	5517	63	29	9	196
5,DD	1009	292	416	22539	543	239	69	4349
6,DD	374	72	69	5777	215	100	7	1030
7,DD	469	162	246	19538	227	78	19	1739
8,DD	683	208	354	20141	384	163	0	4801

9,DD	66	17	56	4528	32	102	104	366
10,DD	247	105	155	49459	497	104	53	725
11,DD	251	131	425	19005	53	54	16	1125
12,DD	339	189	270	19100	67	55	17	1505
13,DD	259	131	74	269801	3	107	20	7071
1,II	186	34	19	583	16240	64	4	74
2,II	50	9	14	142	18382	19	3	255
3,II	21	8	7	20	6981	4	2	225
4,II	79	16	31	70	6485	24	2	108
5,II	432	49	56	200	12693	91	12	1929
6,II	94	15	16	68	2605	36	2	393
7,II	240	49	83	197	8925	63	4	524
8,II	421	39	91	317	9712	43	0	1057
9,II	69	4	4	26	3913	29	7	407
10,II	80	19	15	207	38745	83	4	357
11,II	556	125	175	1076	22125	126	18	1479
12,II	297	57	58	228	16312	42	4	1034
13,II	218	18	14	139	206605	59	0	2261
1,UK	173	127	62	257	25	6559	8	25
2,UK	55	82	202	704	9	30789	121	468
3,UK	26	19	50	28	20	4659	5	416
4,UK	64	42	99	90	51	5552	18	99
5,UK	336	121	327	231	191	13429	49	2483
6,UK	237	60	174	223	128	3100	14	730
7,UK	164	67	201	181	71	9873	14	917
8,UK	207	109	167	440	148	11376	0	1830
9,UK	42	15	354	90	71	4176	75	1114
10,UK	736	228	397	681	220	45487	55	870
11,UK	232	119	127	323	80	13557	46	983
12,UK	123	211	33	154	22	10170	17	1214
13,UK	556	237	0	175	6	197376	42	3931
1,DK	7	2	2	58	1	3	318	48
2,DK	2	2	11	50	2	6	2552	31
3,DK	4	1	4	6	2	2	539	53
4,DK	4	2	3	13	1	6	402	18
5,DK	42	10	21	68	12	29	1740	299
6,DK	7	1	3	8	3	6	190	97
7,DK	7	3	8	11	2	5	509	92
8,DK	0	0	0	0	0	0	0	0
9,DK	38	29	40	68	2	19	1308	161
10,DK	93	20	28	457	204	528	6241	425
11,DK	6	2	14	35	1	9	1233	193
12,DK	18	6	18	72	4	12	1394	205
13,DK	24	14	9	43	2	58	31890	649
1,ROW	1008	218	226	901	346	386	67	9362
2,ROW	468	174	174	586	0	62	225	194307
3,ROW	48	110	55	190	105	40	29	94658
4,ROW	81	36	35	179	106	550	50	7861
5,ROW	767	304	235	854	508	791	187	188751
6,ROW	502	138	160	914	335	550	43	84019
7,ROW	473	216	257	1031	289	570	144	304473
8,ROW	265	250	244	190	28	352	0	256116
9,ROW	350	101	317	440	266	675	246	121286
10,ROW	897	227	240	877	470	1296	127	398435

11,ROW	672	239	492	2630	192	974	206	101730
12,ROW	490	374	141	971	115	875	112	250715
13,ROW	1605	201	45	217	8	2902	49	3542738

PARAMETER

LSB(I) labour supply

/FF 234587
 BL 46612
 NL 76065
 DD 355491
 II 171359
 UK 274375
 DK 29951
 ROW 4223943 /

KSB(I) capital services supply

/FF 417571
 BL 47458
 NL 107523
 DD 222537
 II 257638
 UK 162255
 DK 32589
 ROW 2467985 /

GOVREV(I) proportional income tax revenue

/FF 26542
 BL 11626
 NL 14168
 DD 69643
 II 35124
 UK 55921
 DK 12954
 ROW 1506520 /

ALLOWB(I) allowances

/FF 137315
 BL 24857
 NL 39422
 DD 188944
 II 101743
 UK 129563
 DK 14771
 ROW 2214852 /

TRANSFERB(I) lump sum transfer

/FF 114195,48366
 BL 4795,69340
 NL 9907,27740
 DD 31975,50640
 II 12089,08670
 UK 19692,25350
 DK 10590,02760
 ROW 1014905,91100 /

PUBEXPB(I) public expenditure

/FF 98500

BL 16200
 NL 22600
 DD 110000
 II 58700
 UK 106600
 DK 14300
 ROW 1658768 /

TABLE TTB(I,SUBN) VAT tax rates

	1	2	3	4	5	6	7	8	9	10	11	12	13
FF	.070	.176	.176	.176	.176	.176	.176	.333	.176	.070	.176	.176	.0860
BL	.060	.160	.160	.160	.160	.160	.160	.250	.160	.060	.160	.160	.0714
NL	.040	.180	.180	.180	.180	.180	.180	.180	.180	.040	.180	.180	.0730
DD	.065	.130	.130	.130	.130	.130	.130	.130	.130	.065	.130	.130	.0730
II	.035	.150	.150	.150	.150	.150	.150	.200	.150	.035	.150	.150	.0340
UK	.000	.150	.150	.150	.150	.150	.150	.150	.150	.000	.150	.150	.0580
DK	.220	.220	.220	.220	.220	.220	.220	.220	.220	.220	.220	.220	.1540
ROW	.100	.100	.100	.100	.100	.100	.100	.100	.100	.100	.100	.100	.1000

PARAMETERS

TARB(I,SUBN,I) tariffs on consumption

;
 TARB(I,"1","ROW")=0,02;
 TARB(I,"2","ROW")=0,02;
 TARB(I,"3","ROW")=0,07;
 TARB(I,"4","ROW")=0,05;
 TARB(I,"5","ROW")=0,05;
 TARB(I,"6","ROW")=0,06;
 TARB(I,"7","ROW")=0,08;
 TARB(I,"8","ROW")=0,06;
 TARB(I,"9","ROW")=0,06;
 TARB(I,"10","ROW")=0,04;
 TARB(I,"11","ROW")=0,09;
 TARB(I,"12","ROW")=0,04;
 TARB("ROW","1",I)=0,05;
 TARB("ROW","2",I)=0,02;
 TARB("ROW","3",I)=0,05;
 TARB("ROW","4",I)=0,04;
 TARB("ROW","5",I)=0,03;
 TARB("ROW","6",I)=0,05;
 TARB("ROW","7",I)=0,04;
 TARB("ROW","8",I)=0,02;
 TARB("ROW","9",I)=0,02;
 TARB("ROW","10",I)=0,2;
 TARB("ROW","11",I)=0,12;
 TARB("ROW","12",I)=0,03;
 TARB("ROW".SUBN,"ROW")=0;

PARAMETERS

* elasticity of substitution between
 DELTA2(I) different consumption categories
 DELTA3(I,N) home goods and composite imported goods
 DELTA4(I,N) imports from different source countries
 A3(SUBN,I,I)
 LSB(I) labour supply
 KSB(I) capital services supply

GOVREV(I) proportional income tax revenue
 ALLOWB(I) allowences
 TRANSFERB(I) lump sum transfer
 PUBEXPB(I) public expenditure
 TINC(I)
 A5(I,SUBN)
 :
 DELTA2(I) = 1,1
 :
 DELTA3(I,N) = 1,5
 :
 DELTA4(I,N) = 2,0
 :
 A3(SUBN,I,II) = A3(SUBN,I,II)*scale
 :
 LSB(I) = LSB(I)*SCALE
 :
 KSB(I) = KSB(I)*SCALE
 :
 GOVREV(I) = GOVREV(I)*SCALE
 :
 ALLOWB(I) = ALLOWB(I)*SCALE
 :
 TRANSFERB(I) = TRANSFERB(I)*SCALE
 :
 PUBEXPB(I) = PUBEXPB(I)*SCALE
 :
 A5(I,SUBN) = SUM(II,A3(SUBN,II,I)*(1+TARB(I,SUBN,II))*(1+TTB(I,SUBN)))
 :
 * VARIABLE LABOUR SUPPLY

SCALARS

ELLSUP elasticity of labour supply /0,15/
 RATIO endowment-labour supply /1,75/

PARAMETER

ELEIS(I) elasticity of leisure
 EB(I) labour endowment
 LLB(I) leisure demand
 DELTA1(I) elasticity of substitution between L-goods
 FULLINC(I) full income
 INCTAXRB(I) proportional income tax rate
 FULLDISP(I) full disposable income
 TOTCONS(I) total consumption
 SLL(I) share of leisure expenditure to full disposable income
 SE(I) ratio of time endowment value and full disposable income
 CL(I) share parameter of leisure

* see p.158

* elasticity of leisure

$$ELEIS(I) = - ELLSUP*(1/(RATIO-1))$$

* labour endowment

$$EB(I) = RATIO*LSB(I)$$

* leisure demand

$$LLB(I) = EB(I) - LSB(I)$$

* full income

```

FULLINC(I) = EB(I) + KSB(I)
:
* income tax rate
INCTAXRB(I) = GOVREV(I)/(LSB(I)+KSB(I)-ALLOWB(I))
:
* full disposable income
FULLDISP(I) = (FULLINC(I))*(1-INCTAXRB(I)) + ALLOWB(I)*INCTAXRB(I) +
      TRANSFERB(I)
:
* total consumption
TOTCONS(I) = SUM(SUBN,A5(I,SUBN))
:
* share of leisure expenditure to full disposable income
* see p.158
SLL(I) = LLB(I)*(1-INCTAXRB(I))/FULLDISP(I)
:
* ratio of time endowment value and full disposable income
* see p.158
SE(I) = EB(I)*(1-INCTAXRB(I))/FULLDISP(I)
:
* elasticity of substitution
DELTA1(I) = (SE(I) - SLL(I) - ELEIS(I))/(1-SLL(I))
:
* share parameter of leisure
CL(I) = LLB(I)/(FULLDISP(I)*(1/(1-INCTAXRB(I))))**DELTA1(I)
:
PARAMETERS
C1(I,N)
C2(I,N)
C2B(I,N)
C3(I,N,I)
PROVA(I,subn)
CC(I)
:
* share parameter of total consumption
CC(I) = TOTCONS(I)/FULLDISP(I)
:
C1(I,SUBN) = A5(I,SUBN)/SUM(SUBNN,A5(I,SUBNN))
:
C2(I,SUBN)$(A5(I,SUBN) NE 0) = (A3(SUBN,I,I)*(1+TTB(I,SUBN))**DELTA3(I,SUBN))/A5(I,SUBN)
:
C2B(I,SUBN)$(A5(I,SUBN) NE 0) = (A5(I,SUBN) - A3(SUBN,I,I)*(1+TTB(I,SUBN))
      /A5(I,SUBN)
:
C3(I,SUBN,II)$(ORD(II) NE ORD(I) AND A5(I,SUBN) NE 0) =
      (A3(SUBN,II,I)*((1+TARB(I,SUBN,II))*(1+TTB(I,SUBN)))**DELTA4(I,SUBN))/
      (A5(I,SUBN) - A3(SUBN,I,I)*(1+TTB(I,SUBN)))
:
display
C2B
:

```