Appendix: The Two-Regional Computable General Equilibrium (2SCGE) Model

Basic Structure of the Static 2SCGE Model

The database used for the 2SCGE model is the two inter-regional social accounting matrix (SAM), which encompasses the inter-regional input–output table of competitive imports for the region comprising the four disaster-affected prefectures of Iwate, Miyagi, Fukushima, and Ibaraki and the non-disaster region comprising the prefectures plus Tokyo, Hokkaido, Osaka, and Kyoto except the above four prefectures.[1] The base data used in the SAM is a 2005 inter-regional input–output table of all 47 prefectures created jointly by Professor Yoshifumi Ishikawa and the Mitsubishi Research Institute.

Next, we constructed the two-regional computable general equilibrium (2SCGE) model with the addition of a recursive dynamic dimension.[2] The 2SCGE model comprises 15 agents (1 household, 11 industries, 1 company, 1 regional government, and 1 investment bank) in the two regions, 11 commodity markets, and the two production factor markets of labor and capital. To this, we add the two agents i.e., the central government and overseas sector. Then, labor and capital total endowments are exogenously fixed, and we assume no transfers outside the region, although both labor and capital can move between industries within the region. In addition, we make unemployment endogenous and social security benefits to the

[1]Please refer to Chapter 2 of the Tokunaga and Okiyama (eds) (2014) for more information on this SAM.

[2]For the regional CGE model, see Tokunaga et al. (2003), Hosoe et al. (2010), EcoMod Modeling School (2012), and Okiyama et al. (2014).

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household sector endogenous in the 2SCGE model. Specifically, concerning the former we incorporated the following Eq. (A.3-33) of a Phillips curve-type formula into the 2SCGE model.[3]

$$\sum_{a \in A} PL^o \cdot L_a^o + \overline{LW^o} \cdot ER = PL^o \cdot \left(\overline{LS^o} - UNEMP^o\right) \qquad (A.3-33)$$

$$\left(\frac{PL^o \cdot PCINDEX^o}{PLZ^o \cdot PCINDEXZ^o} - 1\right) = phillips^o \left(\frac{UNEMP^o / \overline{LS^o}}{UNEMPZ^o / \overline{LS^o}} - 1\right) \qquad (A.3-58)$$

where $UNEMP^o(UNEMPZ^o)$ and $PCINDEX^o(PCINDEXZ^o)$ represent the unemployment (initial unemployment) and consumer commodity price index of the Laspeyres formula (initial consumer price index) of region o respectively, $phillips^o$ represents a Phillips parameter, L_a^o and $PL^o(PLZ^o)$ represent the labor and wage rate (initial wage rate) respectively, and $\overline{LS^o}, \overline{LW^o}$ and ER represent the labor endowment (exogenous), labor demand from the rest of world (exogenous), and exchange rate respectively.

Concerning the latter, we incorporated the following Eq. (A.3-30) in order to reflect an increasing aging population. That is, the allowance to the household sector from regional government ($TEGH^o$ in region o) is composed of income compensation to the unemployed person and social security expenditures (exogenous $\overline{TEPS^o}$) such as pension benefits that are tied to price changes.

$$TEGH^o = trep^o(PL^o \cdot UNEMP^o) + PCINDEX^o \cdot \overline{TEPS^o} \qquad (A.3-30)$$

Where $trep^o$ represents the replacement rate in region o.

Then, we explain the structure of each sector in the 2SCGE model: domestic production, households, savings and investment, trade, and regional and central government.

Domestic Production Sector

The domestic production sector has the nested structure of production shown in Fig. A.1-1. Each production sector $a(a \in A)$ in region $o(o \in S)$ is assumed to produce XD_a^o of 1 commodity $c(c \in C)$ and to maximize their profits and face a multi-level production function. In level 1 (A1), an industry in sector a constrained by the Leontief technology takes the production function using each intermediate input good XC_{ca}^o aggregated from 11 commodities and the added value KL_a^o. Since the producer price PD_a^o of sector a in region o holds true for the "zero profit condition," it follows that income = production costs. In level 2 (A2) on the right, we arrive at

[3]The 2SCGE model of Okiyama and Tokunaga (2014, Appendix 1) in which we assume that there is no relation between unemployment and inflation should be viewed as a simple 2SCGE model. In practice, however, this simple 2SCGE model (2014) seems realistic. This is because in most regions, a quasi-Phillips curve exists. Thus, we construct the new 2SCGE model with a Phillips curve-type formulation of Eq. (A.3-58) in a regional labor markets.

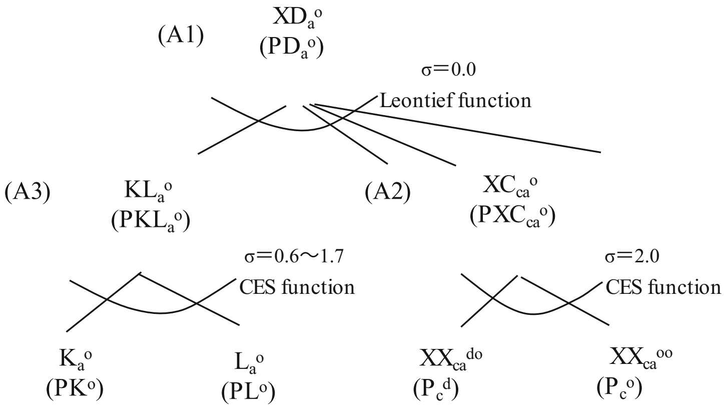

Fig. A.1-1 Structure of production sector

the intermediate goods aggregated for the 11 commodities from the composite commodity according to the Armington assumption XX_{ca}^{do} input from origin $d \in R$ in region d to destination $o \in S$ in region o, under the constraint of constant returns to scale CES technology, and the o intra-regional composite commodity according to the Armington assumption XX_{ca}^{oo}. In addition, we arrive at PXC_{ca}^{o}, the price of the intermediate goods aggregated from sector a of region o, by the income definition, considering the zero profit condition for intermediate goods. In addition, even the added value portion (A3) is derived from the labor L_a^o and capital K_a^o from sector a of the destination region o under the constraint of constant returns to scale CES technology in the same manner as the intermediate goods sector. Then, the producer price PD_a^o of sector a in region o holds true for the "zero profit condition." Thus, it can be derived from income = production costs. Since the return to capital PK^o and wage rate PL^o for the destination region o can move between industries within region o, they are identical for all industries in region o. In addition, we arrive at PXC_a^o, the price of the intermediate goods aggregated from sector a in region o, by the income definition, taking account of the zero profit condition for intermediate goods.

Household Sector

In the household sector, we have formulated the behavior maximizing the level of household utility UH^o as shown in Fig. A.1-2. At level 1 (B1), households in the destination region o maximize the linear-homogeneous Cobb–Douglas utility function for the goods HC_c^o aggregated under the budgetary constraints $CBUD^o$. In addition, at level 2 (B2), we derive the aggregated goods from the composite commodity according to the Armington assumption XH_c^{do} imported from region

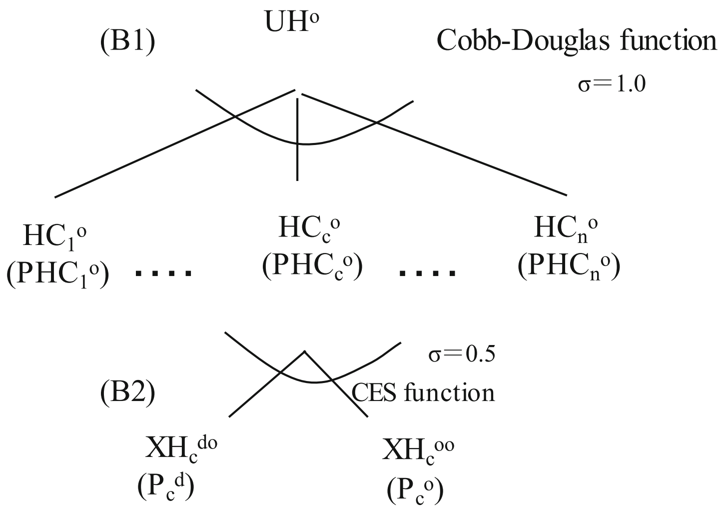

Fig. A.1-2 Structure of household sector

d in origin region $d \in R$ to destination $o \in S$ in region o under the constant returns to scale CES technology constraint and the intra-regional o composite commodity according to the Armington assumption XH_c^{oo}. In addition, we arrive at the price PHC_c^o of the aggregated goods c, by the income definition, taking account of the zero profit condition for such goods. Household income comprises employment income, capital income, social security benefits, property income, and receipts from other current transfers. In addition, the household budget $CBUD^o$ comprises payments of income tax from household income, household savings, social contributions, and payments from property income and other current transfers. Furthermore, household savings is calculated from household income, assuming a fixed propensity to save.

Savings and Investment Sector

Figure A.1-3 illustrates that the savings and investment sector has the same structure as the household sector. The 2SCGE model is closed to prior savings, and in terms of investment, an agent called a "bank" allots savings S^o to investment demand IC_c^o from 11 goods in accordance with the Linear-homogeneous Cobb–Douglas utility function. The savings as shown by Eq. (A.3-13) include the savings of household SH^o, company SN^o, regional government SLG^o, and central government SCG^o, in addition to income transfers SDB^o to offset inter-regional current account balances and overseas savings SF^o to offset a region's external current

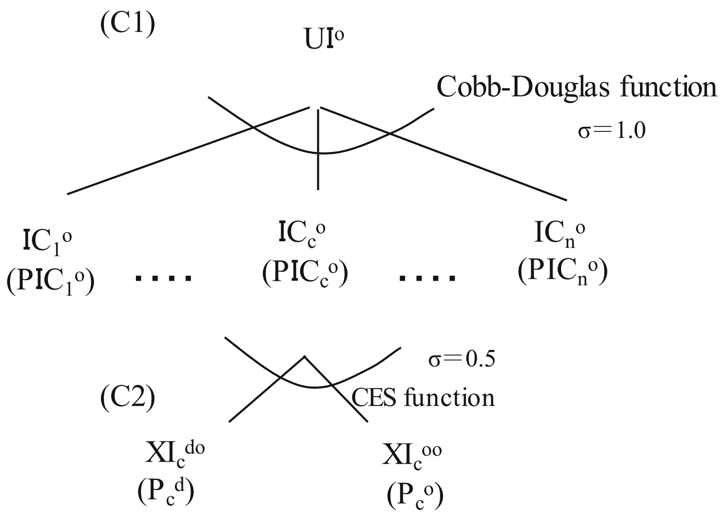

Fig. A.1-3 Structure of investment sector

account balances.[4] Hayashiyama et al. (2011), Okiyama et al. (2014), and others used a static inter-regional CGE model to indicate that income transfers are positive for savings in each region. In this study, however, we add a recursive dynamic dimension to the 2SCGE model by reflecting savings in the inter-regional current account balances as is. In other words, an inter-regional current account deficit negatively impacts a region's savings. This is because, as suggested by Hosoe et al. (2010), in the static model, a current account deficit limited to one period is considered "debt that need not be repaid," so there is no problem with deeming it to be an income transfer, whereas in a dynamic model "debt must be repaid at some point in time with interest," so an inter-regional current account deficit cannot be deemed an income transfer. In this study, however, we would deal with an income transfer as an inter-regional current account deficit for the following reason. This is because the D2SCGE model is a recursive dynamic model in the first reason, and a current account of a region comprising four disaster-affected prefectures will fall into the deficit from the surplus in the intensive reconstruction period because of the fiscal measures in the second reason. If an inter-regional current deficit is regarded as debt that needs to be repaid, the economic spinoff effect of the fiscal measures will be canceled out by the income transfer from the disaster-affected region to the non-disaster affected region. On the other hand, we need to take the inter-regional

[4]Since inter-regional transfers of income cannot be identified with the two-regional SAM, we created a dataset for the 2SCGE model that incorporates the difference between the amounts of imports and exports for each region when allocating the central government's savings to regional governments in each region.

current account between the disaster-affected region and the non-disaster affected region into consideration. This is because the inter-regional current account surplus of the disaster-affected region that had been kept as a supply power to the Kanto region from the Fukushima Nuclear Power Station cannot cancel out under the D2SCGE model, though production in the electricity, gas, and heat-water supply decreased deeply. Therefore, we must pay attention to the following point. The inter-regional current account surplus of the disaster-affected region that has kept more than one trillion yen could have a negative effect on the regional economy of the disaster area continuously. On the other hand, the 2SCGE model treats each region's external current account deficit (foreign savings) as an exogenous variable, and we do not regard this as a problem because the exchange rate is deemed to be an endogenous variable. In addition, at level 2 (C2), we arrive at the aggregated goods IC_c^o from the composite commodity according to the Armington assumption XI_c^{do} imported from region d in origin region $d \in R$ to region o in destination $o \in S$ under the constant returns to scale CES technology constraint and the intra-regional o composite commodity according to the Armington assumption XI_c^{oo}. In addition, we arrive at PIC_c^o the price of the aggregated goods c, by the income definition, taking account of the zero profit condition for such goods.

$$S^o = SH^o + SN^o + SLG^o + SCG^o + SDB^o + SF^o \cdot ER \qquad (A.3-13)$$

Structure of the Trade Sector

Although the trade sector includes exports and imports between each region and the foreign sector, as shown in Fig. A.1-4, trade also occurs through imports and exports between the regions. Specifically, the structure incorporated into the 2SCGE model allocates products produced in region d for the domestic market XDD_c^d and for export E_c^d, with (D1) derived by solving the problem of sales maximization under the constraint of the Constant Elasticity of Transformation function. In addition, for the composite commodity according to the Armington assumption, which is the composite commodity for domestic supply X_c^d comprising producer goods for the domestic market and imported goods M_c^d, (D2) is derived by solving the constrained optimization problem by minimizing its total costs subject to the CES function constraint. The prices for the domestic market PDD_c^d and the composite commodity according to the Armington assumption P_c^d are both derived from the "zero profit condition." The export price PE_c^d and the import price PM_c^d are calculated by multiplying the international price by exchange rate ER, but the import price includes customs duty tt_c and commodity tax on imported goods tm_c. The 2SCGE model fixes the foreign-currency denominated international price and, in the trade balance formula, it sets net overseas transfers of labor $\overline{NLW^o}$ and net overseas transfers of capital $\overline{NKW^o}$ as exogenous variables for foreign savings SF^o in region o, whereas the sum of property and transfer incomes BOP^o and the

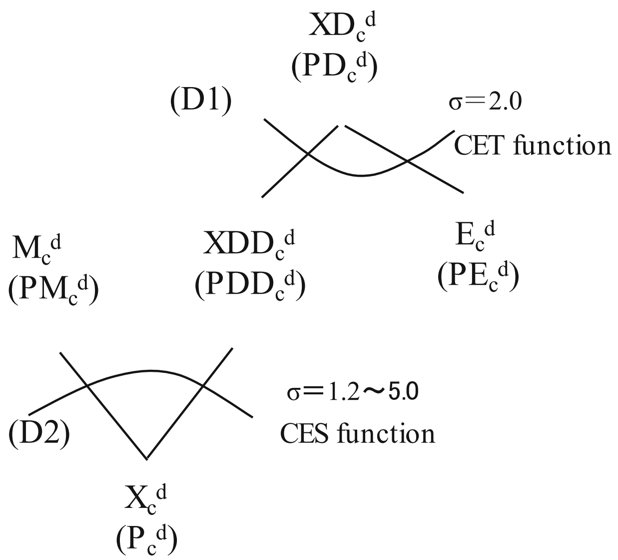

Fig. A.1-4 Structure of trade sector

common exchange rate for the regions are set as endogenous variables. So, we must take the following point into consideration. The exchange rate that is changed by the trade balances of the disaster-affected region has an impact on the price for the composite commodity in the non-disaster region.

Government Sector

Here, we explain the relationship between regional and central governments, which coexist. The central government itself does not engage in spending. Instead, its function is to reallocate the taxes it collects to the regional governments of the two regions, as well as to create savings by taking a fixed proportion of the tax revenue and allocating it to the savings sector of the two regions. Meanwhile, the regional governments in the two regions have budgets that contain the difference between the revenues generated from tax receipts and regional allocation tax grants, etc. and the subsidies disbursed to each production sector. These budgets are then multiplied by a fixed ratio to create savings, and expenditures comprise social security benefits to the household sector and transfers to other institutional sectors and the like.

Setting Elasticity of Substitution and Other Parameters

We estimated the function parameters for each sector with a calibration method that used the two-regional SAM data with 2005 as the benchmark year. However, estimating the function parameters requires that one of the parameters must depend on an external database. Thus, when describing the setting of these parameters, we referenced the values used in GTAP7.1 for the elasticity of substitution for labor and capital in the production sector and the elasticity of substitution for the CES-type (Armington) function of the trade sector. Then, referencing previous studies by Ban (2007), Hayashiyama et al. (2011), and others, we set the inter-regional elasticity of substitution for the production sector, the inter-regional elasticity of substitution for the household and investment sectors, and the elasticity of substitution of the CET-type function for the trade sector. These are summarized in Table A.1–1. In addition to setting the Phillips parameter for each region, we used time-series data from the past to arrive at an estimate of approximately −0.15 for the national figure. However, we used −0.45 for the disaster-affected region and −0.40 for the non-disaster region so that the labor markets in each region will not have full employment even in 2035.

How to Calculate Equivalent Variation

Suppose that we have two different policy regimes: the "benchmark equilibrium"(that will be denoted by the superscript "0" in the sequel) and the "proposed change"(i.e. the policy simulation, denoted by the superscript "1" in the sequel). We would like to measure the welfare effect of the "proposed change". We can use the monetary measure for this change in welfare: the equivalent variation (EV), which measures the household budget at current prices that would be equivalent to the "proposed change" in terms of its impact on utility.

In the "benchmark equilibrium" the commodity prices PD_c^0 of commodity c and household budget $CBUD^0$. Under the "proposed equilibrium" the prices are changed to PD_c^1 whereas the household budget turns out to be $CBUD^1$.

First we define the price index of the cost of living of the "proposed change" relative to the one in the "benchmark equilibrium": PCD_10.

$PCD10 = \prod_c \left(PD_c^1\right)^{\alpha H_c} / \prod_c \left(PD_c^0\right)^{\alpha H_c}$ where αH_c is cobb-Douglas preference parameter for private consumption goods.

Secondly we define the equivalent variation as follows: the equivalent variation is the difference between the household budget of the "proposed change", deflated by the price index of the cost of living, and the household budget of the "benchmark equilibrium".

Table A.1–1 List of elasticity of substitution setup in this model

Production sector	Elasticity of substitution between capital-labor in the CES function	Elasticity of transformation in CET function	Elasticity of substitution of ARMINGTON function	Elasticity of substitution between intermediate goods of different orgin in the CES function	Elasticity of substitution between final goods of different orgin in the CES function
Agriculture and forestry	0.6	2.0	2.7	2.0	0.5
Fisheries	0.6	2.0	1.2	2.0	0.5
Foods and Beverage	1.2	2.0	2.0	2.0	0.5
Electrical devices and parts	1.3	2.0	4.2	2.0	0.5
Motor vehicles and parts	1.3	2.0	2.8	2.0	0.5
Other manufacturing products	1.3	2.0	3.2	2.0	0.5
Construct	1.4	2.0	1.9	2.0	0.5
Electricity,gas and heat-water supply	1.3	2.0	2.8	2.0	0.5
Commerce	1.3	2.0	1.9	2.0	0.5
Transport	1.7	2.0	1.9	2.0	0.5
Financial and insurance,Real estate, Communcation, Public adminstration,Eduction and Servics etc.	1.3	2.0	1.9	2.0	0.5

$$EV = CBUD^1/PCD\_10 - CBUD^0$$

Then considering time period, the equivalent variation in year t EV_t is given by the following equation.

$EV_t = CBUD_t^1/PCD_t10 - CBUD^0 \times (1 + growth)^t$ where $CBUD^0 \times (1 + growth)^t$ is on a steady-state growth path that is a 0.6% potential growth rate [$growth$].

Sets, Variables, Parameters, and Equations of the Static 2SCGE Model

Sets

$a \in A$	Production sectors
$c \in C$	Commodities
$o, d \in S, R$	Regions (o is the region of origin and d is the region of destination)

Endogenous Variables

Price Variables

PL^o	Wage rate in region o
$(PLZ^o$	Initial wage rate in region o=1)
PK^o	Return to capital in region o
PD_a^o	Producer price of production sector a in region o
$(PDZ_a^o$	Initial producer price of production sector a in region o=1)
P_c^o	Price of composite commodity$c$ in region o from imports and domestic production
PXC_{ca}^o	Price of aggregate intermediate input of production sector a in region o
PKL_a^o	Price level of capital-labor bundle of production sector a in region o
PHC_c^o	Price of aggregate commodity c for household demand of region o
$(PHCZ_c^o$	initial price of aggregate commodity c for household demand of region o=1)
PIC_c^o	Price of aggregate commodity c for investment demand of region o
PDD_c^d	Price of domestic output $c$delivered to market being produced in region d
PE_c^d	Export price in domestic currency of domestic output c produced in region d

PM_c^d	Import price in domestic currency of commodities c produced in region d
$PCINDEX^o$	Consumer commodity price index of the Laspeyres formula of region o
($PCINDEXZ^o$	Initial consumer commodity price index of the Laspeyres formula of region o=1)
ER	Exchange rate

Quantity Variables

L_a^o	Labor demand by production sector a of region o
$UNEMP^o$	Unemployment in region o
($UNEMPZ^o$	Initial Unemployment in region o)
K_a^o	Capital demand by production sector a of region o
XD_a^o	Domestic production of production sector a in region o
XC_{ca}^o	Aggregate intermediate input c of production sector a in region o
XX_{ca}^{oo}	Composite commodity c produced in region o as intermediate input to production sector a in region o
XX_{ca}^{do}	Composite commodity c produced in region d as intermediate input to production sector a in region o
KL_a^o	Demand of capital-labor bundle of production sector a in region o
HC_c^o	Household demand in region o of aggregate commodity c
(HCZ_c^o	Initial household demand in region o of aggregate commodity c)
XH_c^{oo}	Household consumption demand in region o for composite commodity c being produced in region o
XH_c^{do}	Household consumption demand in region o for composite commodity c being produced in region d
IC_c^o	Demand for investment in region o by aggregate commodity c
XI_c^{oo}	Demand for investment in region o for composite commodity c being produced in region o
XI_c^{do}	Demand for investment in region o for composite commodity c being produced in region d
G_c^o	Regional government consumption demand in region o for composite commodity c
N_c^o	Company consumption demand in region o for composite commodity c
E_c^d	Exports of commodity c being produced in region d
M_c^d	Imports of commodity c being produced in region d
XDD_c^d	Domestic output c being produced in region d and supplied to markets
X_c^d	Domestic sales of composite commodity c from imports and domestic production in region d

DEX_c^{do} Exports to region *o* composite commodity *c* being produced in region *d*

DIM_c^{do} Imports to region *o* composite commodity *c* being produced in region *d*

Value Variables

Y^o Household income of region *o*

HLS^o Income of household's labor in region *o*

HKS^o Income of household's capital in region *o*

$CBUD^o$ Consumption budget of the household in region *o*

($CBUDZ^o$ Initial consumption budget of the household in region *o*)

$LGRBU^o$ Budget of regional government in region *o*

$CGRBU$ Budget of central government

S^o Total savings in region *o*

SH^o Household savings in region *o*

SLG^o Regional government savings in region *o*

SCG^o Central government savings in region *o*

SN^o Company savings in region *o*

SF^o Foreign savings in region *o* (in foreign currency)

BOP^o Balance of the capital account with property income sector and current transfer sector in region *o*

SDB^o Balance of the regional capital account in region *o*

$TRDH^o$ Direct tax revenues from household in region *o*

$TRDN^o$ Direct tax revenues from company in region *o*

$DDTR^o$ Direct tax receipts to regional government in region *o* from direct tax sector

$GDDTR$ Direct tax receipts to central government from direct tax sector

$DIDR^o$ Indirect tax receipts to regional government in region *o* from indirect tax sector

$GDIDT$ Indirect tax receipts to central government from indirect tax sector

$TRPT^o$ Total indirect production tax revenues in region *o*

$TRTT^o$ Total tariff revenues in region *o*

$TRMT^o$ Total import tax revenues in region *o*

$TRCT^o$ Total sales tax revenues in region *o*

$TGGS^o$ Transfer from central government to regional government in region *o*

PTW Expenditure from ROW to property income sector in foreign currency

CTW Expenditure from ROW to current transfer sector in foreign currency

$TEGH^o$ Social benefits to the household sector in region *o* from regional government in region *o*

Exogenous Variables

Factor Variables (Quantity)

$\overline{LS^o}$	Labor endowment including the unemployment in region *o* (working population)
$\overline{KS^o}$	Capital endowment in region *o*
$\overline{NKS^o}$	Income of company's capital in region *o*
$\overline{LGKS^o}$	Income of regional government's capital in region *o*
$\overline{CGKS^o}$	Income of central government's capital from region *o*

Value Variables

$\overline{TEHG^o}$	Transfers from household in region *o* to regional government in region *o*
$\overline{TEHN^o}$	Transfers from household in region *o* to company in region *o*
$\overline{TEPC^o}$	Social benefits except unemployment benefits to the household sector in region *o* from regional government in region *o*
$\overline{TENH^o}$	Transfers from company in region *o* to regional government in region *o*
$\overline{TEGG^o}$	Transfers from regional government to regional government in region *o*
$\overline{TGG^o}$	Transfers from regional government in region *o* to central government
$\overline{NCG^o}$	Transfers from company in region *o* to central government
$\overline{LW^o}$	Labor demand in region *o* from ROW in foreign currency
$\overline{LWS^o}$	Labor endowment in region *o* to ROW in foreign currency
$\overline{KW^o}$	Capital demand in region *o* from ROW in foreign currency
$\overline{KWS^o}$	Capital endowment in region *o* from ROW in foreign currency
$\overline{PIWS}$	Receipts to ROW from property income sector in foreign currency
$\overline{CIWS}$	Receipts to ROW from current transfer sector in foreign currency
$\overline{HPI^o}$	Expenditure from household in region *o* to property income sector
$\overline{HPIS^o}$	Receipts from property income sector to household in region *o*
$\overline{NPI^o}$	Expenditure from company in region *o* to property income sector
$\overline{NPIS^o}$	Receipts from property income sector to company in region *o*
$\overline{GPI^o}$	Expenditure from regional government in region *o* to property income sector
$\overline{GPIS^o}$	Receipts from property income sector to regional government in region *o*

$\overline{HCT^o}$ Expenditure from household in region o to current transfer sector
$\overline{HCTS^o}$ Receipts from current transfer sector to household in region o
$\overline{NCT^o}$ Expenditure from company in region o to current transfer sector
$\overline{NCTS^o}$ Receipts from current transfer sector to company in region o
$\overline{GCT^o}$ Expenditure from regional government in region o to current transfer sector
$\overline{GCTS^o}$ Receipts from current transfer sector to regional government in region o

Price Variables

$\overline{PWE_c}$ World price of exports commodity c
$\overline{PWM_c}$ World price of imports commodity c

Parameters

Function Parameters

$aF1_a^o$ Efficiency parameter for capital-labor bundle in production sector a in region o (In level 1(A1) in Fig. A.1-1).
$aF2_a^o$ Efficiency parameter in the production function of sector a in region o (the added value portion (A3) in Fig. A.1-1).
$\sigma F2_a$ Elasticity of substitution between capital and labor in the CES function of sector a (the added value portion (A3) in Fig. A.1-1).
$\gamma F2_a^o$ CES distribution parameter in the production function of sector a in region o(the added value portion (A3) in Fig. A.1-1).
σT_c Elasticities of transformation in the CET function
σA_c Elasticity of substitution of the Armingtion function
σR_c Inter –regional elasticity of substitution for intermediate goods c in the CES function
σHI_c Inter –regional elasticity of substitution for final goods c in the CES function
γT_c CET distribution parameter regarding destination of domestic output c
γA_c CES distribution parameter of Armingtion function of commodity c
$\beta_{XX_{ca}^{do}}$ Shift parameter in the CES function of production sector a in region o of composite commodity c being produced in region d

$\beta_{XH_c^{do}}$ Shift parameter in the CES function of household demand in region o of composite commodity c being produced in region d
$\beta_{XI_c^{do}}$ Shift parameter in the CES function of investment demand in region o of composite commodity c being produced in region d
aT_c Shift parameter in the CET function of production sector of commodity c
aA_c Efficiency parameter of the Arimington function of commodity c
αH_c^o Cobb-Douglas preference parameter for the household consumption of commodity c in region o
αI_c^o Cobb-Douglas preference parameter for the investment of commodity c in region o

General Parameters

io_{ca}^o Technical coefficients of intermediate input
$hmps^o$ Household's marginal propensity to save in region o
$nmps^o$ Company's marginal propensity to save in region o
$\mathrm{lg}mps^o$ Regional government's marginal propensity to save in region o
$cgmps^o$ Central government's marginal propensity to save in region o
shG_c^o Marginal share of consumption spending on commodity c for regional government in region o
shN_c^o Marginal share of consumption spending on commodity c for company in region o
tm_c^d Commodity tax rate on imports commodities c
tt_c^d Customs duty of commodities c
ts_c^d Sales tax of commodities c
tp_a^d Production tax rate of production sector a
sp_a^d Production subsidies rate of production sector a
htd^o Direct tax rate by household in region o
ntd^o Direct tax rate by company in region o
ddt^o Distribution rate of direct tax revenues to region o
idt^o Distribution rate of indirect tax revenues to region o
$phillips^o$ Phillips parameter in region o
$trep^o$ Replacement ratio in region o

Other Variables

UH^o Household utility in region o
UI^o Investment agent utility in region o
PCD^o Price index of the cost of livings in region o
EV^o Equivalent variation in region o
$RGRP^o$ Real gross regional products in region o

Equations of 2SCGE Model

Production Equations

(A1)

$$\begin{pmatrix} \text{Max.} \quad PD_a^o \cdot XD_a^o - PKL^o \cdot KL_a^o - \sum_{c \in C} PXC_{ca}^o \cdot XC_{ca}^o \\ \text{s.t.} \quad XD_a^o = \min\left[\frac{KL_a^o}{b_a^o}, \frac{XC_{1a}^o}{io_{1a}^o}, \frac{XC_{2a}^o}{io_{2a}^o}, \cdots\right] \end{pmatrix}$$

$$KL_a^o = b_a^o \cdot XD_a^o = \frac{XD_a^o}{aF1_a^o} \quad (\text{A.3} - 1)$$

$$XC_{ca}^o = io_{ca}^o \cdot XD_a^o \quad (\text{A.3} - 2)$$

$$PD_a^o \cdot XD_a^o = PKL_a^o \cdot KL_a^o + \sum_{c \in C} PXC_{ca}^o \cdot XC_{ca}^o \quad (\text{A.3} - 3)$$

(A2)

$$\begin{pmatrix} \text{Max.} \quad PXC_{ca}^o \cdot XC_{ca}^o - \sum_{d \in R} P_c^d \cdot XX_{ca}^{do} \\ \text{s.t.} \quad XC_{ca}^o = \left[\sum_{d \in R} \beta_{XX_{ca}^{do}} \cdot XX_{ca}^{do\,\frac{\sigma R_c - 1}{\sigma R_c}}\right]^{\frac{\sigma R_c}{\sigma R_c - 1}} \end{pmatrix}$$

$$XX_{ca}^{do} = \left[\frac{1}{\beta_{XX_{ca}^{do}}} \cdot \frac{P_c^d}{PXC_{ca}^o}\right]^{-\sigma R_c} \cdot XC_{ca}^o \quad (\text{A.3} - 4)$$

$$PXC_{ca}^o \cdot XC_{ca}^o = \sum_{d \in R} P_c^d \cdot XX_{ca}^{do} \quad (\text{A.3} - 5)$$

(A3)

$$\begin{pmatrix} \text{Max.} \quad PKL^o \cdot KL_a^o - \left(PL^o \cdot L_a^o + PK^o \cdot K_a^o\right) \\ \text{s.t.} \quad KL_a^o = aF2_a^o \cdot \left(\gamma F2_a^o \cdot K_a^{o\,\frac{-(1-\sigma F2_a)}{\sigma F2_a}} + \left(1 - \gamma F2_a^o\right) L_a^{o\,\frac{-(1-\sigma F2_a)}{\sigma F2_a}}\right)^{\frac{-\sigma F2_a}{1-\sigma F2_a}} \end{pmatrix}$$

$$K_a^o = \gamma F2_a^{o^{\sigma F2_a}} PK^{o^{-\sigma F2_a}} \left(\gamma F2_a^{o^{\sigma F2_a}} PK^{o^{(1-\sigma F2_a)}} + (1-\gamma F2_a)^{\sigma F2_a} PL^{o^{(1-\sigma F2_a)}}\right)^{\frac{\sigma F2_a}{1-\sigma F2_a}} \cdot \left(\frac{KL_a^o}{aF2_a^o}\right) \quad (\text{A.3}-6)$$

$$L_a^o = \left(1-\gamma F2_a^o\right)^{\sigma F2_a} PL^{o^{-\sigma F2_a}} \left(\gamma F2_a^{o^{\sigma F2_a}} PK^{o^{(1-\sigma F2_a)}} + \left(1-\gamma F2_a^o\right)^{\sigma F2_a} PL^{o^{(1-\sigma F2_a)}}\right)^{\frac{\sigma F2_a}{1-\sigma F2_a}} \cdot \left(\frac{KL_a^o}{aF2_a^o}\right) \quad (\text{A.3}-7)$$

$$PKL_a^o \cdot KL_a^o = PL^o \cdot L_a^o + PK^o \cdot K_a^o \quad (\text{A.3}-8)$$

Household Equations

(B1)

$$\left(\begin{array}{ll} \text{Max.} & UH^o = \prod_{c=1}^{n} HC_c^{o^{\alpha H_c^o}} \\ \text{s.t.} & CBUD^o = \sum_{c \in C} PHC_c^o \cdot HC_c^o \end{array}\right)$$

$$PHC_c^o \cdot HC_c^o = \alpha H_c^o \cdot CBUD^o \quad (\text{A.3}-9)$$

(B2)

$$\left(\begin{array}{ll} \text{Max.} & PHC_c^o \cdot HC_c^o = \sum_{d \in R} P_c^d \cdot XH_c^{do} \\ \text{s.t.} & HC_c^o = \left[\sum_{d \in R} \beta_{XH_c^{do}} \cdot XH_c^{do^{\frac{\sigma HI_c - 1}{\sigma HI_c}}}\right]^{\frac{\sigma HI_c}{\sigma HI_c - 1}} \end{array}\right)$$

$$XH_c^{do} = \left[\frac{1}{\beta_{XH_c^{do}}} \cdot \frac{P_c^d}{PHC_c^o}\right]^{-\sigma HI_c} \cdot HC_c^o \quad (\text{A.3}-10)$$

$$PHC_c^o \cdot HC_c^o = \sum_{d \in R} P_c^d \cdot XH_c^{do} \quad (\text{A.3}-11)$$

Saving and Investment Equations

(C1)

$$\begin{pmatrix} \text{Max.} \quad UI^o = \prod_{c=1}^{n} IC_c^{o^{\alpha IC_c^o}} \\ \text{s.t.} \quad S^o = \sum_{c \in C} PIC_c^o \cdot IC_c^o \end{pmatrix}$$

$$PIC_c^o \cdot IC_c^o = \alpha I_c^o \cdot S^o \qquad (A.3-12)$$

$$S^o = SH^o + SN^o + SLG^o + SCG^o + SDB^o + SF^o \cdot ER \qquad (A.3-13)$$

(C2)

$$\begin{pmatrix} \text{Max.} \quad PIC_c^o \cdot IC_c^o - \sum_{d \in R} P_c^d \cdot XI_c^{do} \\ \text{s.t.} \quad IC_c^o = \left[\sum_{d \in R} \beta_{XI_c^{do}} \cdot XI_c^{do^{\frac{\sigma HI_c - 1}{\sigma HI_c}}} \right]^{\frac{\sigma HI_c}{\sigma HI_c - 1}} \end{pmatrix}$$

$$XI_c^{do} = \left[\frac{1}{\beta_{XI_c^{do}}} \cdot \frac{P_c^d}{PIC_c^o} \right]^{-\sigma HI_c} \cdot IC_c^o \qquad (A.3-14)$$

$$PIC_c^o \cdot IC_c^o - \sum_{d \in R} P_c^d \cdot XI_c^{do} \qquad (A.3-15)$$

Trade Equations

(D1)

$$\begin{pmatrix} \text{Max.} \quad PDD_c^d \cdot XDD_c^d + PE_c^d \cdot E_c^d \\ \text{s.t.} \quad XD_c^d = aT_c^d \left(\gamma T_c^d \cdot E_c^{d^{\frac{-(1-\sigma T_c)}{\sigma T_c}}} + \left(1 - \gamma T_c^d\right) XDD_c^{d^{\frac{-(1-\sigma T_c)}{\sigma T_c}}} \right)^{\frac{-\sigma T_c}{1-\sigma T_c}} \end{pmatrix}$$

$$E_c^d = \gamma T_c^{d^{\sigma T_c}} PE_c^{d^{-\sigma T_c}} \left(\gamma T_c^{d^{\sigma T_c}} PE_c^{d^{1-\sigma T_c}} + \left(1 - \gamma T_c^d\right)^{\sigma T_c} \cdot PDD_c^{d^{1-\sigma T_c}} \right)^{\frac{\sigma T_c}{1-\sigma T_c}} \left(\frac{XD_c^d}{aT_c^d} \right) \qquad (A.3-16)$$

$$XDD_c^d = \left(1-\gamma T_c^d\right)^{\sigma T_c} PDD_c^{d^{-\sigma T_c}} \left(\gamma T_c^{d^{\sigma T_c}} PE_c^{d^{1-\sigma T_c}} + \left(1-\gamma T_c^d\right)^{\sigma T_c} \cdot PDD_c^{d^{1-\sigma T_c}}\right)^{\frac{\sigma T_c}{1-\sigma T_c}} \left(\frac{XD_c^d}{aT_c^d}\right) \quad (A.3-17)$$

$$\left(1+tp_c^d - sp_c^d\right)PD_c^d \cdot XD_c^d = PE_c^d \cdot E_c^d + PDD_c^d \cdot XDD_c^d \quad (A.3-18)$$

(D2)

$$\begin{pmatrix} \text{Max.} & PM_c^d \cdot M_c^d + PDD_c^d \cdot XDD_c^d \\ \text{s.t.} & X_c^d = aA_c^d\left(\gamma A_c^d \cdot M_c^{d^{\frac{-(1-\sigma A_c)}{AT_c}}} + \left(1-\gamma A_c^d\right)XDD_c^{d^{\frac{-(1-\sigma A_c)}{\sigma A_c}}}\right)^{\frac{-\sigma A_c}{1-\sigma A_c}} \end{pmatrix}$$

$$M_c^d = \gamma A_c^{d^{\sigma A_c}} PM_c^{d^{-\sigma A_c}} \left(\gamma A_c^{d^{\sigma A_c}} PM_c^{d^{1-\sigma A_c}} + \left(1-\gamma A_c^d\right)^{\sigma A_c} \cdot PDD_c^{d^{1-\sigma A_c}}\right)^{\frac{\sigma A_c}{1-\sigma A_c}} \left(\frac{X_c^d}{aA_c^d}\right) \quad (A.3-19)$$

$$XDD_c^d = \left(1-\gamma A_c^d\right)^{\sigma A_c} PDD_c^{d^{-\sigma A_c}} \left(\gamma A_c^{d^{\sigma A_c}} PM_c^{d^{1-\sigma A_c}} + \left(1-\gamma A_c^d\right)^{\sigma A_c} \cdot PDD_c^{d^{1-\sigma A_c}}\right)^{\frac{\sigma A_c}{1-\sigma A_c}} \left(\frac{X_c^d}{aA_c^d}\right) \quad (A.3-20)$$

$$P_c^d \cdot X_c^d = PM_c^d \cdot M_c^d + \left(1+ts_c^d\right)PDD_c^d \cdot XDD_c^d \quad (A.3-21)$$

$$PM_c^d = \left(1+tt_c^d + tm_c^d\right)\overline{PWM_c} \cdot ER \quad (A.3-22)$$

$$PE_c^d = \overline{PWE_c} \cdot ER \quad (A.3-23)$$

Inter-regional Trade Equations

$$DEM_c^{do} = \sum_{a \in A} XX_{ca}^{do} + XH_c^{do} + XI_c^{do} \qquad o \neq d \quad (A.3-24)$$

$$DIM_c^{do} \equiv DEX_c^{do} \quad (A.3-25)$$

$$SDB^o = \sum_{c,d \in C,R} P_c^d \cdot DIM_c^{do} - \sum_{c,d \in C,R} P_c^d \cdot DEX_c^{do} \quad (A.3-26)$$

Government Equations

$$P_c^o \cdot G_c^o = shG_c^o\left(LGRBU^o - SLG^o - TEGH^o - \overline{TEGG^o} - \overline{GPI^o} - \overline{GCT^o} - \overline{TGG^o}\right) \quad (A.3-27)$$

$$SLG^o = \lg mps^o \cdot LGRBU^o \quad (A.3-28)$$

$$SCG^o = cgmps^o \cdot CGRBU^o \quad (A.3-29)$$

$$TEGH^o = trep^o(PL^o \cdot UNEMP^o) + PCINDEX^o \cdot \overline{TEPS^o} \quad (A.3-30)$$

Company Equations

$$SN^o = nmps^o\left(PK^o \cdot \overline{NKS^o} + \overline{TEHN^o} + \overline{NPIS^o} + \overline{NCTS^o}\right) \quad (A.3-31)$$

$$P_c^o \cdot N_c^o = shN_c^o\left(PK^o \cdot \overline{NKS^o} + \overline{TEHN^o} + \overline{NPIS^o} - SN^o - \overline{TENH^o} - TRDN^o - \overline{NPI^o} - \overline{NCT^o} - \overline{NCG^o}\right) \quad (A.3-32)$$

Market Clearing Equations

$$\sum_{a \in A} PL^o \cdot L_a^o + \overline{LW^o} \cdot ER = PL^o \cdot \left(\overline{LS^o} - UNEMP^o\right) \quad (A.3-33)$$

$$PL^o \cdot \left(\overline{LS^o} - UNEMP^o\right) = PL^o \cdot HLS^o + \overline{LWS^o} \cdot ER \quad (A.3-34)$$

$$\sum_{a \in A} PK^o \cdot K_a^o + \overline{KW^o} \cdot ER = PK^o \cdot \overline{KS^o} \quad (A.3-35)$$

$$PK^o \cdot \overline{KS^o} = PK^o\left(HKS^o + \overline{NKS^o} + \overline{LGKS^o} + \overline{CGKS^o}\right) + \overline{KWS^o} \cdot ER \quad (A.3-36)$$

$$X_c^d = \sum_{a \in A} \sum_{o \in S} XX_{ca}^{do} + \sum_{o \in S} \left(XH_c^{do} + XI_c^{do}\right) + N_c^d + G_c^d \quad (A.3-37)$$

$$\sum_{c \in C} M_c^o \cdot \overline{PWM_c} + \overline{LWS^o} + \overline{KWS^o} = \sum_{c \in C} E_c^o \cdot \overline{PWE_c} + SF^o + \overline{LW^o} + \overline{KW^o} + BOP^o \quad (A.3-38)$$

$$\sum_{o \in S} BOP^o = (PIW + CTW) - \left(\overline{PIWS} + \overline{CTWS}\right) \quad (A.3-39)$$

$$\sum_{o \in S} \left(\overline{HPI^o} + \overline{NPI^o} + \overline{GPI^o}\right)/ER + PIW = \sum_{o \in S} \left(\overline{HPIS^o} + \overline{NPIS^o} + \overline{GPIS^o}\right)/ER + \overline{PIWS} \qquad (A.3-40)$$

$$\sum_{o \in S} \left(\overline{HCT^o} + \overline{NCT^o} + \overline{GCT^o}\right)/ER + CTW = \sum_{o \in S} \left(\overline{HCTS^o} + \overline{NCTS^o} + \overline{GCTS^o}\right)/ER + \overline{CTWS} \qquad (A.3-41)$$

$$CGRBU = \sum_{o \in S} \left(SCG^o + \overline{TGGS^o}\right) \qquad (A.3-42)$$

$$\sum_{o \in S} (TRDH^o + TRDN^o) = \sum_{o \in S} DDTR^o + GDDTR \qquad (A.3-43)$$

$$\sum_{o \in S} (TRTT^o + TRMT^o + TRPT^o) = \sum_{o \in S} DIDT^o + GDIDT \qquad (A.3-44)$$

Definition Equations

$$DDTR^o = ddt^o(TRDH^o + TRDN^o) \qquad (A.3-45)$$

$$DIDT^o = idt^o(TRTT^o + TRMT^o + TRPT^o) \qquad (A.3-46)$$

$$TRTT^o = \sum_{c \in C} tt_c \cdot \overline{PWM_c} \cdot ER \cdot M_c^o \qquad (A.3-47)$$

$$TRMT^o = \sum_{c \in C} tm_c \cdot \overline{PWM_c} \cdot ER \cdot M_c^o \qquad (A.3-48)$$

$$TRCT^o = \sum_{c \in C} ts_c \cdot PDD_c^o \cdot XDD_c^o \qquad (A.3-49)$$

$$TRPT^o = \sum_{a \in A} tp_a \cdot PD_c^o \cdot XD_c^o \qquad (A.3-50)$$

$$TRDH^o = htd^o \cdot Y^o \qquad (A.3-51)$$

$$TRDN^o = ntd^o\left(PK^o \cdot \overline{NKS^o} + \overline{TEHN^o} + \overline{NPIS^o} + \overline{NCTS^o}\right) \qquad (A.3-52)$$

$$Y^o = PL^o \cdot HLS^o + PK^o \cdot HKS^o + \overline{TEHN^o} + TEGH^o + \overline{HPIS^o} + \overline{HCTS^o} \qquad (A.3-53)$$

$$CBUD^o = Y^o - TRDH^o - SH^o - \overline{TEHG^o} - \overline{TEHN^o} - \overline{HPI^o} - \overline{HCT^o} \quad (A.3-54)$$

$$LGRBU^o = PK^o \cdot \overline{LGKS^o} + \overline{TEHG^o} + \overline{TEGG^o} + DDTR^o + DIDT^o + \overline{GPIS^o} + \overline{GCTS^o} + TGGS^o - \sum_{a \in A} sp_a \cdot PD_a^o \cdot XD_a^o \quad (A.3-55)$$

$$CGRBU = \sum_{o \in S} \left(PK^o \cdot \overline{CGKS^o} + \overline{TGG^o} + \overline{NCG^o} + TRCT^o\right) + GDDTR + GDIDT \quad (A.3-56)$$

$$PCINDEX^o = \frac{\sum_{c \in C} PHC_c^o \cdot HCZ_c^o}{\sum_{c \in C} PHCZ_c^o \cdot HCZ_c^o} \quad (A.3-57)$$

$$\left(\frac{PL^o \cdot PCINDEX^o}{PLZ^o \cdot PCINDEXZ^o} - 1\right) = phillips^o \left(\frac{UNEMP^o / \overline{LS^o}}{UNEMPZ^o / \overline{LS^o}} - 1\right) \quad (A.3-58)$$

Equation Delivered to Other Variables

$$PCD^o = \prod_{a,c \in A,C} PD_a^{o^{\alpha H_c^o}} / \prod_{a,c \in A,C} PDZ_a^{o^{\alpha H_c^o}} \quad (A.3-59)$$

$$EV^o = \frac{CBUD^o}{PCD^o} - CBUDZ^o \quad (A.3-60)$$

$$RGRP^o = \sum_{c \in C} \left(HC_c^o + IC_c^o + G_c^o + N_c^o + E_c^o - M_c^o\right) + \sum_{c,d \in C,R} \left(DEX_c^{do} - DIM_c^{do}\right) \quad (A.3-61)$$

Variables, Parameters and Equations of the Dynamic 2SCGE (D2SCGE) Model

Variables and Parameters

Modified Variables and Parameters

PK_a^o	Return to capital of production sector *a* in region *o*
K_a^o	Capital stock of production sector *a* in region *o*
HKS_a^o	Household income from capital stock of production sector *a* in region *o*
$\overline{KS^o}$	Capital endowment in region *o* (deletion)
$\overline{NKS_a^o}$	Company income from capital stock of production sector *a* in region *o*
$\overline{LGKS_a^o}$	Income of regional government from capital stock of production sector *a* in region *o*
$\overline{CGKS_a^o}$	Income of central government from capital stock of production sector *a* in region *o*
$\overline{KW_a^o}$	Demand of Capital stock from ROW to production sector *a* in region *o* (in foreign currency)
$\overline{KWS_a^o}$	Endowment of Capital stock to ROW from production sector *a* in region *o* (in foreign currency)

Additional Variables and Parameters

IT_t^o	Total investment demand in region *o* in period *t*
$PKAVG_t^o$	Average return to capital in region *o* in period *t*
INV_{ta}^o	Actual investment of production sector *a* in region *o* in period *t*
$INVZ_a^o$	Initial actual investment of production sector *a* in region *o* in period *t*
aIT^o	A certain percentage of investment agent's utility in region *o*

Modified Equations and Additional Equations

Modified Equations

$$K_a^o = \gamma F2_a^{o^{\sigma F2_a}} PK_a^{o^{-\sigma F2_a}} \left(\gamma F2_a^{o^{\sigma F2_a}} PK_a^{o^{(1-\sigma F2_a)}} + (1-\gamma F2_a)^{\sigma F2_a} PL^{o^{(1-\sigma F2_a)}} \right)^{\frac{\sigma F2_a}{1-\sigma F2_a}} \cdot \left(\frac{KL_a^o}{aF2_a^o} \right) \tag{A.3 – 6′}$$

$$L_a^o = \left(1 - \gamma F2_a^o\right)^{\sigma F2_a} PL^{o^{-\sigma F2_a}} \left(\gamma F2_a^{o^{\sigma F2_a}} PK_a^{o^{(1-\sigma F2_a)}} + \left(1 - \gamma F2_a^o\right)^{\sigma F2_a} PL^{o^{(1-\sigma F2_a)}}\right)^{\frac{\sigma F2_a}{1-\sigma F2_a}} \cdot \left(\frac{KL_a^o}{aF2_a^o}\right) \quad (A.3 - 7')$$

$$PKL_a^o \cdot KL_a^o = PL^o \cdot L_a^o + PK_a^o \cdot K_a^o \quad (A.3 - 8')$$

$$SN^o = nmps^o\left(PK_a^o \cdot \overline{NKS_a^o} + \overline{TEHN^o} + \overline{NPIS^o} + \overline{NCTS^o}\right) \quad (A.3 - 31')$$

$$P_c^o \cdot N_c^o = shN_c^o\left(PK_a^o \cdot \overline{NKS^o} + \overline{TEHN^o} + \overline{NPIS^o} - SN^o - \overline{TENH^o} - TRDN^o - \overline{NPI^o} - \overline{NCT^o} - \overline{NCG^o}\right) \quad (A.3 - 32')$$

$$K_a^o + \overline{KW_a^o} \cdot ER = \left(HKS_a^o + \overline{NKS^o} + \overline{LGKS^o} + \overline{CGKS^o}\right) + \overline{KWS_a^o} \cdot ER \;\; (A.3 - 35' \text{ and } A.3 - 36') \quad (A3 - 37)$$

$$\sum_{c \in C} M_c^o \cdot \overline{PWM_c} + \overline{LWS^o} + \sum_{a \in A} \overline{KWS_a^o} = \sum_{c \in C} E_c^o \cdot \overline{PWE_c} + SF^o + \overline{LW^o} + \sum_{a \in A} \overline{KW_a^o} + BOP^o \quad (A.3 - 38')$$

$$TRDN^o = ntd^o\left(\sum_{a \in A} PK_a^o \cdot \overline{NKS_a^o} + \overline{TEHN^o} + \overline{NPIS^o} + \overline{NCTS^o}\right) \quad (A.3 - 52')$$

$$Y^o = PL^o \cdot HLS^o + \sum_{a \in A} PK_a^o \cdot HKS_a^o + \overline{TEHN^o} + TEGH^o + \overline{HPIS^o} + \overline{HCTS^o} \quad (A.3 - 53')$$

$$CBUD^o = Y^o - TRDH^o - SH^o - \overline{TEHG^o} - \overline{TEHN^o} - \overline{HPI^o} - \overline{HCT^o} \quad (A.3 - 54')$$

$$LGRBU^o = \sum_{a \in A} PK_a^o \cdot \overline{LGKS_a^o} + \overline{TEHG^o} + \overline{TEGG^o} + DDTR^o + DIDT^o + \overline{GPIS^o} + \overline{GCTS^o} + TGGS^o - \sum_{a \in A} sp_a \cdot PD_a^o \cdot XD_a^o \quad (A.3 - 55')$$

$$CGRBU = \sum_{a \in A, o \in S} PK_a^o \cdot CGKS_a^o + \sum_{o \in S}\left(\overline{TGG^o} + \overline{NCG^o} + TRCT^o\right) + GDDTR + GDIDT \quad (A.3 - 56')$$

Additional Equations: Capital Stock Equations

$$IT_t^o = aIT^o \cdot \prod_{c \in C} IC_{ct}^{o^{aI_c^o}} \qquad (A.3-62)$$

$$PKAVG_t^o = \frac{\sum_{a \in A} PK_{at}^o \cdot K_{at}^o}{\sum_{a \in A} K_{at}^o} \qquad (A.3-63)$$

$$INV_{at}^o = INVZ_a^o \cdot \sqrt{PK_{at}^o / PKAVG_t^o} \qquad (A.3-64)$$

$$INV_{at}^o = IT_t^o \cdot \frac{INV_{at}^o}{\sum_{a \in A} INV_{at}^o} \qquad (A.3-65)$$

$$K_{at}^o = K_{at-1}^o + INV_{at}^o \qquad (A.3-66)$$

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