A Guide to the GAMS-input-file

This is a user's guide to the GAMS-input-file of the regional CGE model described throughout section 3. It transforms the mathematical program specified in section 4.1 into an executable computer program based in GAMS (the acronym stands for General Algebraic Modeling System). To make this chapter self-contained we reproduce some introductory material on the construction of a CGE-model in GAMS, however we recommend the reading of GAMS tutorial (Brooke et al., Chap. 2).

We provide the complete GAMS-PROGRAM in this link {click here to download CRS2.GMS}. It’s clearly only a prototype and the numerical values of the parameters and initial values were explained in section 3.2. For a collection of models with similar specification, but somehow more sophisticated, we offer the following link: {Oklahoma State University; Department of Agricultural Economics; RCGE}

In what follows, the GAMS-Program input file is presented and explained in its major components.

Index sets

The application starts with a definition of the main index sets and subsets. A set declaration consists of declaring and specifying the index to be used. Sets should be declared before their subsets. Every declaration consists of a logical name, a label field, followed by a list of elements of the index set. As such, it is the same as indexes used in the equations of the model. They correspond to the subscription notation of table 4.2{click here to go to table 4.2}.

```
$TITLE REGIONAL CGE MODEL FOR OKLAHOMA (1993)(CRS.GMS)
$OFFSYMLIST OFFSYMREF OFFUPPER
SETS
   i          Sectors           /Agr agriculture
                Min mining
                Man manufacture
                SER services/
   ag(i)      Agricultural sectors / AGR/
   nag(i)     Nonagricultural market sectors / MIN, SER, MAN/
   f          Factors           /L labor, K capital, T land/
     fl(f)    Factors not land / L, K/
ALIAS(i,j);
```
A $-sign at the beginning of the program, is used for special commands, i.e., $TITLE, where we introduce the title of the model. All GAMS-statements end with a semicolon. The ALIAS-statement defines an alternative name for an index set (subscript).

**BASE YEAR DATA**

Base year variables are based upon the Social Accounting Matrix (SAM) and are distinguished by "0" as a suffix in their names, i.e., L0(i) states base year labor. GAMS requires a DECLARATION and ASSIGNMENT of each variable or parameter. Here, we declare the base year variables as parameters. GAMS offers flexible arrangements for introducing the parameters (variables). We recommend first to declare (initiate) all the parameters, then use tables to enter data and finally, assign the values.

To provide better readability, parameters are declared by blocks: prices, production, income and expenditure blocks. In GAMS, comment-lines and text in general are introduce by “*” in the first column of a row.

*#####-- DECLARATION OF BASE YEAR VARIABLES (AS PARAMENTERS)*

PARAMETERS

*@Price block*
PL0 Wage rate
PLROC0 Wage rate of rest-of-country
PKROC0 Cap rate of rest-of-country
PK0(i) cap rate
PT0(ag) Land rent
PE0(i) Export price
PM0(i) Import price
PR0(i) Reg price
P0(i) Composite price
PN0 Net output price or value-added price of sector i
PX0(i) Composite price face for producers

*@Production block*
L0(i) Labor demand
LS0 Labor supply by hh
TLS0 Total labor supply
LHHH0 Labor employed by household group
LGOV0 Labor employed by gov
K0(i) capital demand
T0(i) Land demand
KS0 Supply of pri capital
TKS0 Total pri capital supply
TS0 Supply of land
VA0(i) Value added
VO(j,i) Composite intermediate good demand
TV0(i) Composite intermediate good total demand
VR0(j,i) Reg int good demand
VM0(j,i) Imported int good demand
TVR0(i) Reg int good total demand
TVM0(i) Imported int good total demand
IBT0(I) Indirect business taxes
X0(i) Sector output
E0(i) Export of reg product
M0(i) Import
R0(i) Reg supply of reg product

*Income block
LY0 Labor income
KY0 capital income
TY0 Land income
YENT0 Gross Enterprise income
YH0 Household income
DYH0 Disposable hh income
HSAV0 Household saving
SAV0 Total saving
ROWSAV0 Saving from rest-of-world
TRGOV0 Gov transfer to hh
REMIT0 Remittance from outside the region to household
YGOV0 Gov revenue
ENTY0 Enterprise income distrib to hhs
GOVITR0 Inter gov transfer
GOVBOR0 Government Borrowing
GRP0 Gross regional product

*Expenditure block
HEXP0 Household expend
QRO(i) Demand for reg consump good
QM0(i) Demand for imp consump good
Q0(i) Demand for comp consump good
GOVEXP0 government expenditure
QGOVRO(i) government demand for reg good
QGOVM0(i) government demand for imported good
QGOV0(i) government demand for comp good
QInvRO(i) Invest demand for reg good
QInvM0(i) Invest demand for imported good
QInv0(i) Invest demand for comp good
INV0 Total invest

The following variables are defined as "logical variables". A logical variable takes the value of 1 if the condition stated is true and "0" if not. We use these variables when defining an equation or for assigning value to a particular variable depending on the "true" or "false" condition of a specific condition, i.e., variable NZV takes the value of "1" if both regional and imported intermediate input are used, according to the following graph.

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<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>X</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional</td>
<td>x</td>
<td>x</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Import</td>
<td>x</td>
<td>0</td>
<td>x</td>
<td>0</td>
</tr>
</tbody>
</table>

*NZV T F F F T=TRUE, F=FALSE
*ZVR F F T F
*ZVM F T F T

ZVM(i,J) non imported intermediate demand with-or-without regional intern. demand
ZVR(i,J) only imported intermediate demand
NZV(i,J) both imported intermediate demand and regional demand

ZQM(i) non imported final demand and either none or some regional final demand for household
ZQR(i) only imported final demand for household
NZQ(i) both imported final demand and regional final demand for households

ZGOVM(i)
ZGOVR(i)
NZGOV(i)

ZInvM(i)
ZInvR(i)
NZInv(i)

DECLARATION OF PARAMETERS TO BE CALIBRATED

These parameters are those specified in Table 4.5. {Click here to see table 4.5}. They are declared in the following segment of the application but they will be initialized later.

*#####-- DECLARATION OF PARAMETERS TO BE CALIBRATED.

PARAMETERS

*This parameters are those specified in Table 5.5.

*@Production block
a0(i) composite value added req per unit of output i
a(j,i) req of interm good j per unit of good i
Alpha(i,f) value added share param
Ava(i) value added shift param
RHOv(i) interm input subs param
deltav1(j,i) deltav(j,i) interm input share param
Av(j,i) interm input shift param
RHOx(i) output transformation param
deltax1(i) deltax(i) output share param
Ax(i) output shift param

*@Income block
ktax capital tax rate
sstax factor income tax rate for labor
ttax factor income tax rate for land
retr rate of retained earnings fr ent inc
et enterprise tax rate
hhtax income tax rate for hh
ltr Household Income Transfer Coefficient
mps saving rate
ibtax(i) indirect business tax
beta(i) param calc fr elast of comm demand wrt inc

*@Expenditure block
RHOq consumer demand subs param
deltaq1(i) deltaq(i) consumer demand share param
Aq(i) consumer demand constant eff param
RHOgov gov demand subs param
deltagov1 deltagov gov demand share param
Agov gov demand constant eff param
RHOinv inv gov demand subs param
Data comes from our SAM (Table 2.1). You should note that values from our SAM are scaled to millions of dollars instead of thousands. Though the scaling of our data is not a "must" for solving the model, we strongly recommend scaling. Scaling problems have been found to create more serious problems in more disaggregated models.

Table IOR(i,j) Input-output regional matrix

<table>
<thead>
<tr>
<th></th>
<th>AGR</th>
<th>MIN</th>
<th>MAN</th>
<th>SER</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGR</td>
<td>675.798</td>
<td>8.115</td>
<td>863.991</td>
<td>34.800</td>
</tr>
<tr>
<td>MIN</td>
<td>123.47</td>
<td>2180.942</td>
<td>1258.117</td>
<td>881.343</td>
</tr>
<tr>
<td>MAN</td>
<td>159.671</td>
<td>1390.701</td>
<td>3594.97</td>
<td>3953.2</td>
</tr>
<tr>
<td>SER</td>
<td>381.542</td>
<td>1317.332</td>
<td>5272.186</td>
<td>9752.027</td>
</tr>
</tbody>
</table>

Table IOM(i,j) Input-output import matrix

<table>
<thead>
<tr>
<th></th>
<th>AGR</th>
<th>MIN</th>
<th>MAN</th>
<th>SER</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGR</td>
<td>579.870</td>
<td>5.160</td>
<td>378.422</td>
<td>41.300</td>
</tr>
<tr>
<td>MIN</td>
<td>11.850</td>
<td>1274.869</td>
<td>311.094</td>
<td>385.272</td>
</tr>
<tr>
<td>MAN</td>
<td>446.830</td>
<td>450.977</td>
<td>8835.472</td>
<td>2750.345</td>
</tr>
<tr>
<td>SER</td>
<td>155.160</td>
<td>458.802</td>
<td>1886.710</td>
<td>4188.764</td>
</tr>
</tbody>
</table>

Table VAD(i,f) Value added matrix

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>K</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGR</td>
<td>433.242</td>
<td>571.360</td>
<td>709.066</td>
</tr>
<tr>
<td>MIN</td>
<td>1522.806</td>
<td>2713.109</td>
<td></td>
</tr>
<tr>
<td>MAN</td>
<td>7577.427</td>
<td>4025.159</td>
<td></td>
</tr>
<tr>
<td>SER</td>
<td>20767.388</td>
<td>12042.708</td>
<td></td>
</tr>
</tbody>
</table>

Table HHCONR(i,*) Household consumption demand for regional goods

<table>
<thead>
<tr>
<th></th>
<th>HOUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGR</td>
<td>147.210</td>
</tr>
<tr>
<td>MIN</td>
<td>1587.998</td>
</tr>
<tr>
<td>MAN</td>
<td>2656.085</td>
</tr>
<tr>
<td>SER</td>
<td>30727.366</td>
</tr>
</tbody>
</table>

Table HHCONM(i,*) Household consumption demand for imported goods

<table>
<thead>
<tr>
<th></th>
<th>HOUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGR</td>
<td>181.550</td>
</tr>
<tr>
<td>MIN</td>
<td>141.662</td>
</tr>
<tr>
<td>MAN</td>
<td>5713.705</td>
</tr>
<tr>
<td>SER</td>
<td>9510.103</td>
</tr>
</tbody>
</table>

Table GOVCONR(i,*) Government consumption demand for regional goods

Deltainv1 deltainv inv gov demand share param Ainvinv gov demand constant eff param
GOV
AGR 12.863
MIN 231.250
MAN 1854.066
SER 1477.995

Table GOVCONM(i,*) Government consumption demand for imported goods
GOV
AGR 20.097
MIN 29.912
MAN 823.846
SER 542.893

Table FYDIST(*,f) Factor income distribution to households

<table>
<thead>
<tr>
<th>L</th>
<th>K</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>31363.057</td>
<td>0.00</td>
</tr>
</tbody>
</table>

TABLE ParamA(*,i) BASE YEAR VALUES FOR INDUSTRY

<table>
<thead>
<tr>
<th>AGR</th>
<th>MIN</th>
<th>MAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>PK0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>PR0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>P0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>PM0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>PE0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>X0</td>
<td>4344.160</td>
<td>12089.784</td>
</tr>
<tr>
<td>R0</td>
<td>1752.557</td>
<td>6282.217</td>
</tr>
<tr>
<td>E0</td>
<td>2591.603</td>
<td>5807.567</td>
</tr>
<tr>
<td>M0</td>
<td>1216.846</td>
<td>2170.418</td>
</tr>
<tr>
<td>IBT0</td>
<td>96.301</td>
<td>666.971</td>
</tr>
<tr>
<td>QINVR0</td>
<td>9.780</td>
<td>19.097</td>
</tr>
<tr>
<td>QINVMO</td>
<td>10.447</td>
<td>15.759</td>
</tr>
<tr>
<td>SIGMAP</td>
<td>1.00001</td>
<td>1.00001</td>
</tr>
<tr>
<td>SIGMAv</td>
<td>1.42</td>
<td>0.5</td>
</tr>
<tr>
<td>SIGMAX</td>
<td>3.90</td>
<td>2.90</td>
</tr>
<tr>
<td>SIGMAq</td>
<td>1.42</td>
<td>0.50</td>
</tr>
<tr>
<td>SIGMAgov</td>
<td>1.42</td>
<td>0.50</td>
</tr>
</tbody>
</table>
\[ \Sigma_{\text{inv}} = 1.42 \quad 0.50 \quad 3.55 \]

\[ 2.00 \]

;  

\textbf{TABLE} \textbf{ParamB}(f,*) \quad \textbf{BASE YEAR VALUES FOR FACTORS} \\
WAGE0 \quad WAGEROC0 \quad FTAX0 \quad RETENT0 \quad \text{CAP0} \\
CAPROC0 \\
\begin{array}{lllll}
L & 1.0 & 1.0 & 6126.715 & 0 \\
K & -1006.686 & 9077.096 & 1 \\
\end{array} \\
1 \\
T & 25.766 & 0 \\
;  

\textbf{TABLE} \textbf{ParamC} (*,*) \quad \textbf{BASE YEAR VALUES FOR HOUSEHOLD GROUPS} \\
HTAX0 \quad HSAV0 \quad TRGOV0 \\
\begin{array}{llll}
HOUSE & 6976.571 & -3869.320 & 11490.516 \\
+ & \text{REMIT0} & \text{ENTYDIS0} \\
HOUSE & 760.824 & 9582.303 \\
;  

\textbf{TABLE} \textbf{ParamD}(g,*) \quad \textbf{BASE YEAR VALUES FOR GOVTS} \\
BOR0 \quad GOVDR0 \quad GOVDM0 \\
\begin{array}{llll}
GOV & 0.0 & 3576.174 & 1416.748 \\
;  

\text{SCALAR} \text{LHHH0} \quad \text{Labor used by household} \quad /107.070/; \\
\text{SCALAR} \text{LGOV0} \quad \text{Labor used by government} \quad /6981.839/; \\
\text{SCALAR} \text{GOVITR0} \quad \text{Inter-government transfers} \quad /8477.813/; \\
\text{SCALAR} \text{YENT0} \quad \text{Enterprise income} \quad /20359.022/; \\
\text{SCALAR} \text{ENTTAX0} \quad \text{Enterprise taxes} \quad /1699.623/; \\
\text{SCALAR} \text{ROWGOV0} \quad \text{Rest of world transfers to government} \quad /4375.094/; \\
\text{SCALAR} \text{ROWSAV0} \quad \text{Saving from ROW} \quad /2789.519/; \\
\text{SCALAR} \text{QINVMSUM0} \quad \text{Investment demand for imported goods} \quad /2659.308/; \\
\text{SCALAR} \text{etaL} \quad \text{Labor migration elasticity} \quad /0.92/; \\
\text{SCALAR} \text{etaK} \quad \text{Capital migration elasticity} \quad /0.92/; \\
\text{Scalar} \text{KMobil} \quad \text{Capital Mobility} \quad /1.0/; \\
;  

\textbf{ASSIGNING VALUES: Initialization of Parameters} \\

Here, we assign a value to each of the base year variables declared previously. This assigning of values should correspond to our SAM. 

*\texttt{@Production block} \\
L0(i) =VAD(i,"L"); \\
K0(i) =VAD(i,"K"); \\
T0(i) =VAD(i,"T"); \\
VA0(i) =sum(f,VAD(i,f)); \\
V0(j,i) =I0R(j,i)+I0M(j,i); \\
TV0(i) =sum(j,V0(i,j)); \\
VM0(j,i) =I0M(j,i); \\
VR0(j,i) =I0R(j,i); \\
TVMO(i) =sum(j,VM0(i,j)); \\
TVRO(i) =sum(j,VR0(i,j)); \\
LHHH0 =LHHH0;
LGOV0 = LGOV0;
LS0 = \sum(i, VAD(i, "L")) + LHHH0 + LGOV0;
X0(i) = ParamA("X0", i);
E0(i) = ParamA("E0", i);
R0(i) = ParamA("R0", i);
KS0(i) = VAD(i, "K");
TKS0 = \sum(i, KS0(i));
TS0(i) = VAD(i, "T");
IBT0(I) = PARAMA("IBT0", I);

* Income block
TRGOV0 = ParamC("HOUSE", "TRGOV0");
LY0 = \sum(i, VAD(i, "L")) + LHHH0 + LGOV0;
KY0 = \sum(i, VAD(i, "K"));
TY0 = \sum(i, VAD(i, "T"));
YENT0 = ParamA("X0", I);
REMITE0 = ParamC("HOUSE", "REMITE0");
YH0 = \sum(f, FYDIST("HH", f)) + ParamC("HOUSE", "ENTRYDis0") + TRGOV0 + REMITE0;
DYH0 = YH0 - ParamC("HOUSE", "HTAX0");
HSAV0 = ParamC("HOUSE", "HSAV0");
HEXP0 = DYH0 - HSAV0 - LHHH0;
SAV0 = ParamB("K", "RETENT0") + ParamC("HOUSE", "HSAV0") + ROWSAV0;
ROWSAV0 = ROWSAV0;
YGOV0 = \sum(i, ParamA("IBT0", i)) + \sum(f, ParamB(f, "FTAX0")) + ParamC("HOUSE", "HTAX0") + ENTTAX0 + ROWGOV0 + GOVITR0;
GRP0 = LY0 + KY0 + TY0 + \sum(i, ParamA("IBT0", i));

* Expenditure block
QR0(i) = HHCONR(i, "HOUSE");
QM0(i) = HHCONM(i, "HOUSE");
Q0(i) = QM0(i) + QR0(i);
GOVEXP0 = ParamD("GOV", "GOVDR0") + ParamD("GOV", "GOVDM0") + ParamC("HOUSE", "TRGOV0") + LGOV0 + GOVITR0;
QGOV0(i) = GOVCONR(i, "GOV");
QGOV0(i) = GOVCONM(i, "GOV");
QGOV0(i) = QGOV0(i) + QGOV0(i);
QINV0(i) = ParamA("QINV0", i);
QINV0(i) = ParamA("QINV0", i);
QINV0(i) = QINV0(i) + QINV0(i);
INV0 = \sum(i, QINV0(i));
M0(i) = ParamA("M0", i);

* Price block
PL0 = ParamB("L", "WAGE0");
PK0(i) = ParamA("PK0", i);
PLROC0 = ParamB("L", "WAGEROC0");
PKROC0 = ParamB("K", "CAPROC0");
PT0(ag) = ParamA("PT0", ag);
PE0(i) = ParamA("PE0", i);
PM0(i) = ParamA("PM0", i);
PR0(i) = ParamA("PR0", i);
P0(i) = ParamA("P0", i);
FX0(i) = (PR0(i) * R0(i) + PM0(i) * M0(i)) / (R0(i) + M0(i));

*---------------------------------------------
* Regional  x  x  0  0  0=zero, x=not zero
* Import x 0 x 0

* N Z V TFFF T=True, F=False
* ZVR F F T F
* ZVM F T F T

ZVM(i,j) = (VM0(i,j) eq 0);
ZVR(i,j) = (VR0(i,j) eq 0) and (VM0(i,j) ne 0);
NZV(i,j) = (VR0(i,j) ne 0) and (VM0(i,j) ne 0);
ZQM(i) = (QM0(i) eq 0);
ZQR(i) = (QR0(i) eq 0) and (QM0(i) ne 0);
NZQ(i) = (QR0(i) ne 0) and (QM0(i) ne 0);
ZGOVM(i) = (QGOVM0(i) eq 0);
ZGOVR(i) = (QGOVR0(i) eq 0) and (QGOVM0(i) ne 0);
NZGOV(i) = (QGOVR0(i) ne 0) and (QGOVM0(i) ne 0);
ZInvM(i) = (QInvM0(i) eq 0);
ZInvR(i) = (QInvR0(i) eq 0) and (QInvM0(i) ne 0);
NZInv(i) = (QInvR0(i) ne 0) and (QInvM0(i) ne 0);

So far, we have assigned values to our base year variables (parameters). Has GAMS read the assignments correctly? Next, we define new parameter to check for accuracy of our assignment statements. If correct, we should get our SAM and a block of unity prices. Though, the DISPLAY statement of GAMS allows the modeler to easily see the assignment results with statements like

DISPLAY PK0, PT0, L0, K0, TSO;

we prefer to define new parameters, so the output will be easier to read and presented in table format. The advantage of this procedure may not be appreciated in small CGE models, but definitely are greatly appreciated in much bigger models.

PARAMETER SAM1 SOCIAL ACCOUNTING MATRIX -BASE YEAR PRICES-;
SAM1(I,"PK")=PK0(I);
SAM1(ag,"PT")=PT0(ag);
SAM1(I,"PE")=PE0(I);
SAM1(I,"PM")=PM0(I);
SAM1(I,"PR")=PR0(I);
SAM1(I,"P")=P0(I);
SAM1(I,"PR")=PR0(I);

PARAMETER SAM2 SOCIAL ACCOUNTING MATRIX -BASE YEAR DATA-;
SAM2(I,"L")=L0(I);
SAM2(I,"K")=K0(I);
SAM2(I,"KS")=KS0(I);
SAM2(I,"T")=T0(I);
SAM2(I,"TS")=TS0(I);
SAM2(I,"VA")=VA0(I);
SAM2(I,"TVR")=TVR0(I);
SAM2(I,"TVM")=TVM0(I);
SAM2(I,"TV")=TV0(I);
SAM2(I,"IBT")=IBT0(I);
SAM2(I,"X")=X0(I);
SAM2(I,"M")=M0(I);
SAM2(I,"R")=R0(I);
SAM2(I,"E")=E0(I);
SAM2(I,"Q")=Q0(I);
SAM2(I,"QR")=QR0(I);
SAM2(I,"QM")=QM0(I);
SAM2(I,"QGOV")=QGOV0(I);


```plaintext
SAM2(I,"GOVR0") = GOVR0(I);
SAM2(I,"GOVMO") = GOVMO(I);
SAM2(I,"INV0") = INV0(I);
SAM2(I,"INVR0") = INVR0(I);
SAM2(I,"INVM0") = INVM0(I);
OPTION DECIMALS=0;
DISPLAY SAM1;
OPTION DECIMALS=3;
DISPLAY SAM2;
DISPLAY V0,VM0,VR0,LS0,PL0, PLROC0,LHHH0,LGOV0,LY0,TY0,
YENT0,REMIT0,YH0,DYH0,YGOV0,GRP0,WSAV0,
TRGOV0,ENTY0,ENTTAX0,GOVBOR0;
```

### PARAMETER CALIBRATION

Calibration is the setting of model parameters in order to make the equilibrium solution fit the data of a given base year (our SAM). The way to perform this adjustment in GAMS is to solve at fixed (consistent) values of observed variables, treating some of the parameters as variables. The solution will then fit the model to the data.

The calibration procedure was introduced in section 2.3. We have linked the text equation that is used in the calibration with each of our definitions; i.e., clicking over the definition

\[ a0(i) = VA0(i)/X0(i); \]

takes you to equation 3.1.2 in our text. Once again, remember that our base year variables are identified by a "0" suffix in the name.

```plaintext
a0(i) = VA0(i)/X0(i);
a(j,i) = V(j,i)/X0(i);
alpha(ag,"K") = VAD(ag,"K")/VA0(ag);
alpha(ag,"T") = VAD(ag,"T")/VA0(ag);
alpha(ag,"L") = 1-alpha(ag,"K")-alpha(ag,"T");
alpha(nag,"K") = VAD(nag,"K")/VA0(nag);
alpha(nag,"L") = 1-alpha(nag,"K");
Ava(ag) = VA0(ag)/Prod(f,VAD(ag,f)**alpha(ag,f));
Ava(nag) = VA0(nag)/PROD(fl,VAD(nag,fl)**alpha(nag,fl));
RHOv(i) = 1-1/ParamA("SIGMAv",i);
deltav1(j,i) *(NZV(j,i)) = (VR0(j,i)/VM0(j,i))**(1-
RHOv(j)) *(PR0(j)/PM0(j));
deltav(j,i) *(NZV(j,i)) = 1/(1+deltav1(j,i));
```

---

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\[
Av(j,i) = \frac{V0(j,i)}{(\text{deltav}(j,i) \cdot V0(j,i)) + (1-\text{deltav}(j,i)) \cdot VR0(j,i)^{\text{RHOv}(j)}}
\]

\[
\text{RHOx}(i) = 1 + \frac{1}{\text{ParamA}("SIGMAx",i)}
\]

\[
\text{deltax1}(i) = \left( \frac{R0(i)}{E0(i)} \right)^{1-\text{RHOx}(i)} \cdot \frac{PR0(i)}{PE0(i)}
\]

\[
\text{deltax}(i) = \frac{1}{1 + \text{deltax1}(i)}
\]

\[
\text{Ax}(i) = \frac{X0(i)}{\text{deltax}(i) \cdot E0(i)^{\text{RHOx}(i)} + (1-\text{deltax}(i)) \cdot R0(i)^{\text{RHOx}(i)}}^{\frac{1}{\text{RHOx}(i)}}
\]

\[
\text{sstax} = \frac{\text{ParamB}("L","FTAX0")}{LY0}
\]

\[
\text{ktax} = \frac{\text{ParamB}("K","FTAX0")}{KY0}
\]

\[
\text{ttax} = \frac{\text{ParamB}("T","FTAX0")}{TY0}
\]

\[
\text{ibtax}(i) = \frac{\text{ParamA}("IBT0",i)}{\text{PR0}(i) \cdot X0(i)}
\]

\[
\text{et} = \frac{\text{ENTTAX0}}{KY0}
\]

\[
\text{hhtax} = \frac{\text{ParamC}("HOUSE","HTAX0")}{YH0}
\]

\[
\text{ltr} = 1
\]

\[
\text{mps} = \frac{\text{ParamC}("HOUSE","HSAV0")}{YH0}
\]

\[
\text{RHOq}(i) = 1 - \frac{1}{\text{ParamA}("SIGMAq",i)}
\]

\[
\text{deltaq1}(i) = \left( \frac{QR0(i)}{QM0(i)} \right)^{1-\text{RHOq}(i)} \cdot \frac{PR0(i)}{PM0(i)}
\]

\[
\text{deltaq}(i) = \frac{1}{1 + \text{deltaq1}(i)}
\]

\[
\text{Aq}(i) = \frac{Q0(i)}{\text{deltaq}(i) \cdot QM0(i)^{\text{RHOq}(i)} + (1-\text{deltaq}(i)) \cdot QR0(i)^{\text{RHOq}(i)}}^{\frac{1}{\text{RHOq}(i)}}
\]

\[
\text{RHOgov}(i) = 1 - \frac{1}{\text{ParamA}("SIGMAgov",i)}
\]

\[
\text{deltagov1}(i) = \left( \frac{QGOVR0(i)}{QGOVM0(i)} \right)^{1-\text{RHOgov}(i)} \cdot \frac{PR0(i)}{PM0(i)}
\]

\[
\text{deltagov}(i) = \frac{1}{1 + \text{deltagov1}(i)}
\]

\[
\text{Agov}(i) = \frac{QGOV0(i)}{\text{deltagov}(i) \cdot QGOM0(i)^{\text{RHOgov}(i)} + (1-\text{deltagov}(i)) \cdot QGOVR0(i)^{\text{RHOgov}(i)}}^{\frac{1}{\text{RHOgov}(i)}}
\]

\[
\text{RHOinv}(i) = 1 - \frac{1}{\text{ParamA}("SIGMAinv",i)}
\]

\[
\text{deltainv1}(i) = \left( \frac{QINVR0(i)}{QINVM0(i)} \right)^{1-\text{RHOinv}(i)} \cdot \frac{PR0(i)}{PM0(i)}
\]

\[
\text{deltainv}(i) = \frac{1}{1 + \text{deltainv1}(i)}
\]

\[
\text{Ainv}(i) = \frac{QINV0(i)}{\text{deltainv}(i) \cdot QINV0(i)^{\text{RHOinv}(i)} + (1-\text{deltainv}(i)) \cdot QINVR0(i)^{\text{RHOinv}(i)}}^{\frac{1}{\text{RHOinv}(i)}}
\]

\[
\beta(i) = \frac{Q0(i) \cdot P0(i)}{\text{HEXP0}}
\]

To check values for the calibration we use the following parameters which allow us to display the results of calibration in a table-like display.

PARAMETER CALIBR PARAMETER CALIBRATED;
CALIBR(I,"A0")=A0(I);
CALIBR(I,"AVA")=AVA(I);
CALIBR(I,"RHOV")=RHOv(I);
CALIBR(I,"RHOQ")=RHOQ(I);
CALIBR(I,"DELTAQ")=DELTAQ(I);
CALIBR(I,"AQ")=AQ(I);
CALIBR(I,"IBTAX")=IBTAX(I);
CALIBR(I,"RHOGOV")=RHOGOV(I);
CALIBR(I,"DELTAGOV")=DELTAGOV(I);
CALIBR(I,"AGOV")=AGOV(I);
CALIBR(I,"RHOINV")=RHOINV(I);

CALIBR(I,"AINV")=AINV(i);
CALIBR(I,"RHOX")=RHOX(i);
CALIBR(I,"DELTAX")=DELTAX(i);
CALIBR(I,"AX")=AX(i);
CALIBR(I,"BETA")=BETA(i);
DISPLAY CALIBR;
DISPLAY a,Av,deltav,alpha,
ktax,sstax,ttax,retr,et,mps,hhtax;

VARIABLE DECLARATION

All symbols belonging to the list of choice variables in the mathematical program should be declared as VARIABLES, not as PARAMETERS. Endogenous variables are given in table 4.3. Every endogenous variable declaration has a logical name followed by a label field (optional).

*##########################################################*
* VARIABLE DECLARATION *
*##########################################################*

* ENDOGENOUS VARIABLES

VARIABLES
Z Objective Function Value

*@Price block
PL Wage rate
PK(i) Capital rate
PKL Capital rate in the long run
PT(ag) Land rent
PN(i) Net price
PR(i) Regional price
P(i) Composite price
PX(i) Composite price faced by consumers

*@Production block
LAB(i) Labor demand
CAP(i) Capital demand
LAND(ag) Land demand
TCAP Total Capital Demand
TLAB Total Labor Demand
LS Labor supply
LMIG Labor migration
KMIG Capital migration
VA(i) Value added
V(j,i) Composite intermediate good demand
VM(j,i) Imported int good demand
VR(j,i) Reg int good demand
R(i) Regional supply
X(i) Output
EXP(i) Export
M(i) Import
TVM(i) Imported int good total demand
TVR(i) Reg int good total demand
TV(i) Composite intermediate good total demand
adjL Labor adjustment

*@Income block
The following statement ensures that we are working with positive variables. All variables may be assigned as positive variables except the "Z" variable which we use in the optimization statement.

```
POSITIVE VARIABLE SLACK, SLACK2;
```

**Equation Declaration**

This section declares the equations of the model which are those presented in Table 4.1. (Click here for table 4.1) Equations are also denoted by symbols. Hence, every equation can be referred to by its logical name.

```
* This section declares the equations of the model
* which are those presented in table 5.1

EQUATIONS

EQZ objective function

*Price block

NETprice(i) net price
Price(i) composite price
Price1(i)
```
*@Production block

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ldemand(i)</td>
<td>labor demand</td>
</tr>
<tr>
<td>KdemandSR(i)</td>
<td>capital demand</td>
</tr>
<tr>
<td>KdemandLR(i)</td>
<td>total demand</td>
</tr>
<tr>
<td>Tdemand(ag)</td>
<td>land demand</td>
</tr>
<tr>
<td>TLdemand</td>
<td>total labor demand</td>
</tr>
<tr>
<td>TKdemand</td>
<td>total capital demand</td>
</tr>
<tr>
<td>VAdemand(i)</td>
<td>value added demand</td>
</tr>
<tr>
<td>Vdemand(j,i)</td>
<td>intermediate demand</td>
</tr>
<tr>
<td>VApdreq1(nag)</td>
<td>value added prod frc</td>
</tr>
<tr>
<td>VApdreq2(ag)</td>
<td>value added prod frc</td>
</tr>
<tr>
<td>Vces(j,i)</td>
<td>ces fcr for int demand</td>
</tr>
<tr>
<td>TVdemand(i)</td>
<td>intermediate total demand</td>
</tr>
<tr>
<td>TVRdemand(i)</td>
<td>int reg total demand</td>
</tr>
<tr>
<td>TVMdemand(i)</td>
<td>int imp total demand</td>
</tr>
<tr>
<td>VRdem(j,i)</td>
<td>demand for int good</td>
</tr>
<tr>
<td>VMdem0(j,i)</td>
<td>demand for imp int good</td>
</tr>
</tbody>
</table>

zero import:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xcet(i)</td>
<td>cet fcr for reg product</td>
</tr>
<tr>
<td>Rsupply(i)</td>
<td>reg supply of reg product</td>
</tr>
<tr>
<td>LSupply</td>
<td>labor supply</td>
</tr>
<tr>
<td>LMIGrat</td>
<td>labor migration</td>
</tr>
<tr>
<td>adjustL</td>
<td>labor migration adjustment</td>
</tr>
<tr>
<td>KMIGrat</td>
<td>capital migration</td>
</tr>
<tr>
<td>KMIGrat1</td>
<td></td>
</tr>
</tbody>
</table>

*@Income block

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyincome</td>
<td>labor income</td>
</tr>
<tr>
<td>AYincome</td>
<td>adjusted labor income</td>
</tr>
<tr>
<td>KYincomeSR</td>
<td>capital income</td>
</tr>
<tr>
<td>KYincomeLR</td>
<td></td>
</tr>
<tr>
<td>Tyincome</td>
<td>land income</td>
</tr>
<tr>
<td>YENTincome</td>
<td>enterprise income</td>
</tr>
<tr>
<td>RETeaarn</td>
<td>Retained earning by enterprises</td>
</tr>
<tr>
<td>YHincome</td>
<td>household income</td>
</tr>
<tr>
<td>DHYincome</td>
<td>disposable income</td>
</tr>
<tr>
<td>HSAVings</td>
<td>household savings</td>
</tr>
<tr>
<td>SAVings</td>
<td>total savings</td>
</tr>
<tr>
<td>INVEST</td>
<td>total investment</td>
</tr>
<tr>
<td>YGOVINCOME</td>
<td>Government income</td>
</tr>
<tr>
<td>INDTAX</td>
<td>Indirect business tax</td>
</tr>
<tr>
<td>GRPRODUCT</td>
<td>gross region product</td>
</tr>
</tbody>
</table>

*@Expenditure block

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHEXPLow</td>
<td>adj. household expenditure</td>
</tr>
<tr>
<td>Qces</td>
<td>ces fcr for consumption</td>
</tr>
<tr>
<td>Qdemand</td>
<td>cons demand for composite good</td>
</tr>
<tr>
<td>QRdem0</td>
<td>cons demand for reg goods</td>
</tr>
<tr>
<td>QRdem1</td>
<td></td>
</tr>
<tr>
<td>QRdem2</td>
<td></td>
</tr>
<tr>
<td>QMDem1</td>
<td></td>
</tr>
<tr>
<td>QMDem2</td>
<td></td>
</tr>
<tr>
<td>GOVEXPend</td>
<td>Gov expenditure</td>
</tr>
<tr>
<td>QGOVces</td>
<td>ces for st and loc gov demand</td>
</tr>
<tr>
<td>QGOVdemand</td>
<td>st and loc gov cons</td>
</tr>
<tr>
<td>QGOVRdem0</td>
<td>st and loc gov reg cons</td>
</tr>
<tr>
<td>QGOVRdem1</td>
<td></td>
</tr>
<tr>
<td>QGOVRdem2</td>
<td></td>
</tr>
<tr>
<td>QGOVMDem1</td>
<td></td>
</tr>
<tr>
<td>QGOVMDem2</td>
<td></td>
</tr>
</tbody>
</table>
QINVces  ces for invest gov demand
QINVemand  invest gov cons
QINVRdem0  invest gov reg cons
QinvRdeml
QinvRdem2
QInvMdem1
QInvMdem2
Mimports(i)  import
*@Equilibrium
COMMequil(i)  comm market equilibrium
Lequil  labor market equilibrium
Kequil(i)  cap market equilibrium
Kequil1
Tequil(ag)  land market equilibrium;

EQUATION DEFINITION

All equations are defined following the algebraic specification
given in Table 4.1. [Click here to see table 4.1.] This section requires
special attention and intense scrutiny. To help the reader, we have
linked each equation definition. Thus, it is possible to move from
GAMS-specification format to its algebraic specification. Furthermore,
each algebraic equation in Table 4.1 is itself linked to the part of
the text where derivation takes place.

In the equation definition, the "=E=" represents an equality-
sign; the greater-or-equal sign is written as =G=, and smaller-or-equal
as =L=. Thus, by comparing with Table 5.1 algebraic specification,
the meaning of each equation is straightforward. Exceptions are equations
involving a dollar expression; i.e., QCES(CI)$NZQ(CI). A dollar
expression indicates that the value of the variable (i.e., the equation
QCES) should be considered only if the expression that follows is true.

*##########################################################*
* *
* EQUATION DEFINITION *
* *
*##########################################################*

*All equations are defined following the algebraic structure
*on table 5.1.

EQZ.. Z =e= sum(i,SLACK(i)+SLACK2(i));

*@Price block
NETprice(i).. PN(i) =e= PX(i)-sum(j,A(j,i)*P(j))-
ibtax(i)*PX(i);
Price(i).. P(i) =e= (PR(i)*R(i)+PM0(i)*M(i))/(R(i)+M(i));
Price1(i).. PX(i) =e= (PR(i)*R(i)+PE0(i)*Exp(i))/(R(i)+Exp(i));

*@Production block
Ldemand(i).. LAB(i) =e= alpha(i,"L") *PN(i)*X(i)/PL;
KdemandSR(i)$Not(Kmobil).. CAP(i) =e= alpha(i,"K")*PN(i)*X(i)/PK;
KdemandLR(i)$Kmobil.. CAP(i) =e= alpha(i,"K")*PN(i)*X(i)/PKL;
Tdemand(ag).. LAND(ag)=e= alpha(ag,"T")*PN(ag)*X(ag)/PT(ag);
TLdem.. TLAB =e= Sum(i,LAB(i));
TKdem.. TCAP =e= Sum(i,CAP(i));
LER.. LS =e= LS0;
LMIGrat.. LMIG =e= etaL*LS0*LOG(PL/PLROC0);
adjustL.. adjL =e= (LS0+LMIG)/LS0;
KMIGrat$(KMobil).. KMIG =e=etaK*(SUM(i,K0(i))*LOG(PKL/PKROC0));
KMIGratS(not KMobil).. KMIG =e= 0;
VAdemand(i).. VA(i)+SLACK(i)+SLACK2(i)=e= a0(i)*X(i);
VAprom1[nag].. VA(nag) =e= (LS0+LMIg)/LS0;

alpha(nag)*LAB(nag)**alpha(nag,"L")*CAP(nag)**
LSupply .. LS =e= LS0;
LMIGrat .. LMIG =e= etaL*LS0*LOG(PL/PLROC0);
adjL.. adjL =e= (LS0+LMIG)/LS0;
KMIGrat$(KMobil).. KMIG =e=etaK*(SUM(i,K0(i))*LOG(PKL/PKROC0));
KMIGratS(not KMobil).. KMIG =e= 0;
VAdemand(i).. VA(i)+SLACK(i)+SLACK2(i)=e= a0(i)*X(i);
VAprom1[nag].. VA(nag) =e= (LS0+LMIg)/LS0;

alpha(nag)*LAB(nag)**alpha(nag,"L")*CAP(nag)**

alpha(nag,\"K\")*LAND(nag)**alpha(nag,\"T\");

TVDemand.. TV =e= sum(j,TV(j,i));
VRdem.. VR =e= sum(j,V(j,i))

*VR(j,i)**RHOv(j)**(1/RHOv(j));

TV Demand.. TV =e= sum(i,V(i,j));

VRdem(j,i)$NZV(j,i)..

VR(j,i) =e= VM(j,i)*((1-deltav(j,i))/
deltav(j,i))

Vces(j,i).. V(j,i) =e= Av(j,i)*(deltav(j,i)*VM(j,i)

**RHOv(j)+(1-deltav(j,i))

RHOv(j));

VRdem0(j,i)$ZVM(j,i) ..

VR(j,i) =e= V(j,i);

VMdem0(j,i)$ZVM(j,i) ..

VM(j,i) =e= 0;

TVRdemand(i).. TVR =e= sum(i,VR(i,j));

TVMdemand(i).. TVM =e= sum(i,VM(i,j));

Xcet(i). ..

X(i) =e=

R(i)*EXP(i)**RHOx(i)

**RHOx(i));

Rsupply(i).. R =e= EXP(i)*((1-

RHOx(i)));

DELtax(i) / DELtax(i)

*PE0(i)/PR(i)**(1/(1-

RHOx(i)));

INDtax.. IBTX =e= Sum(i,ibtax(i)*X(i));

GRProduct.. GRP =e= ALY + KY + TY + IBTX;


@Income block

*ALY is defined for all labor; LY is defined for original household

ALYincome.. ALY =e= PL*(TLAB+LHHH0+LGOV0);
LYincome.. LY =e= ALY+PLROC0*(SQRT(LMig)**2-LMig)*0.5

PL*(SQRT(LMig)**2+LMig)*0.5;

KYincomeSRS(not kmobil).. KY =e= sum(i,PK(i)*CAP(i));
KYincomeLRS(kmobil).. KY =e= sum(i,PKL*CAP(i)+PKROC0*(SQRT(KMIG)**2-KMIG)

*0.5-

PKL*(SQRT(KMIG)**2+KMIG)*0.5;

REtEarn.. RETENT =e= retr*KY;
TYincome.. TY =e= sum(ag,PT(ag)*LAND(a))

YEntIncome.. YENT =e= KY*(1-k tax);

YHIncome .. YH =e = ALY*(1-st tax)

+TY*(1-t tax)+(YENT-RETENT-

et*KY)

+REMIT0+ajdL*TRGOV0

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-((\sqrt{(\text{adjL-1})^2})-(\text{adjL-1}))*0.5)

* (\text{TY}*(1-\text{ttax}))+ (\text{YENT}-\text{RETENT}-

\text{et} \times \text{KY})

+ \text{REMIT0};

\text{DHYincome} .. \text{DHY} = e= \text{YH} \times (1-\text{hhtax});
\text{HSAVings} .. \text{HSAV} = e= \text{mps} \times \text{YH};
\text{SAVings} .. \text{SAV} = e= \text{HSAV}+\text{RETENT}+\text{ROWSAV0};
\text{INVest} .. \text{INV} = e= \text{sum}(i,\text{P}(i) \times \text{QINV}(i));
\text{YGOVincome} .. \text{YGOV} = e= \text{Sum}(i,\text{ibtax}(i) \times \text{PX}(i) \times \text{X}(i))

+ \text{sstax} \times \text{ALY}
+ \text{ktax} \times \text{KY}+\text{et} \times \text{KY}
+ \text{ttax} \times \text{TY}
+ \text{hhtax} \times \text{YH}+\text{GOVBOR0}+\text{GOVITR0};

*@Expenditure block
\text{AHEXPlow} .. \text{AHEXP} = e= \text{DHY}-\text{HSAV}-\text{PL} \times \text{LHHH0};
\text{Qdemand}(i) .. \text{Q}(i) = e= \text{beta}(i) \times \text{AHEXP}/\text{P}(i);  
\text{Qces}(i)$NZQ(i) .. \text{Q}(i) = e= \text{Aq}(i) \times \text{deltaq}(i) \times \text{QM}(i)

** \text{RHOq}(i)+(1-\text{deltaq}(i)) \times \text{QR}(i) \times \text{RHOq}(i)

** (1/RHOq(i));
\text{QRdem0}(i)$NZQ(i) .. \text{QR}(i) = e= \text{QM}(i) \times (1-

\text{deltaq}(i))/\text{deltaq}(i)

** \text{PM0}(i)/\text{PR}(i)**(1/(1-RHOq(i)));
\text{QRdem1}(i)$ZQM(i) .. \text{QM}(i) = e= 0;
\text{QRdem2}(i)$ZQR(i) .. \text{QR}(i) = e= 0;
\text{QMdem2}(i)$ZQR(i) .. \text{QM}(i) = e= 0;
\text{GOVEXPend} .. \text{GOVEXP} = e= \text{sum}(i,\text{P}(i) \times \text{QGOV}(i)) \times \text{adjL}*$

+ \text{TRGOV0}+\text{PL} \times \text{LGOV0}+\text{GOVITR0};
\text{QGOVdemand}(i) .. \text{QGOV}(i) = e= \text{QGOV0}(i);  
\text{QGOVces}(i)$NZGOV(i) .. \text{QGOV}(i) = e= \text{Agov}(i) \times \text{deltagov}(i)

** \text{RHOgov}(i);  
\text{QGOVRdem0}(i)$NZGOV(i) .. \text{QGOVR}(i) = e= \text{QGOVM}(i) \times (1-

\text{deltagov}(i));
\text{QGOVRdem1}(i)$ZGOVM(i) .. \text{QGOVM}(i) = e= 0;
\text{QGOVRdem2}(i)$ZGOVR(i) .. \text{QGOVR}(i) = e= 0;
\text{QGOVRdem2}(i)$ZGOVR(i) .. \text{QGOVM}(i) = e= 0;
\text{QInvMemand}(i) .. \text{QINV}(i) = e= \text{QINV0}(i);
\text{QINVces}(i)$NZInv(i) .. \text{QINV}(i) = e= \text{AINv}(i) \times \text{deltainv}(i) \times \text{QINV}(i)

** \text{RHOinv}(i);  
\text{QINVrdem0}(i)$NZInv(i) .. \text{QINV}(i) = e= \text{QINV0}(i) \times (1-

\text{deltainv}(i));
\text{QINVrdem1}(i)$ZInvM(i) .. \text{QINV}(i) = e= 0;
\text{QINVrdem2}(i)$ZInvR(i) .. \text{QINV}(i) = e= 0;
\text{QINVrdem2}(i)$ZInvR(i) .. \text{QINV}(i) = e= 0;
\text{Mimports}(i) .. \text{M}(i) = e=

\text{TVM}(i)+\text{QM}(i)+\text{QGOVM}(i)+\text{QINV}(i);

*@Equilibrium
COMMequil(i)..
X(i)+M(i)=e=TV(i)+Q(i)+QGOV(i)+QINV(i)+EXP(i);
Lequil.. \text{sum}(i,LAB(i))+LHHH0+LGOV0 =e= LS0+LMIG;
Kequil1$(KMobil).. KMig =e= \text{Sum}(i,CAP(i)-KS0(i));
Kequil(i)$(not KMobil).. CAP(i) =e= KS0(i);
Tequil(ag)..
\text{LAND}(ag) =e= T0(ag);

**STARTING VALUES and BOUNDS**

Before a model is solved, it is necessary to initialize all relevant bounds. Bounds are treated in the same way as parameters. Here, we introduce GAMS language to characterize a variable. A GAMS-variable is characterized by a suffix:

- \text{.L} current level of the variable
- \text{.M} shadow price on the bound
- \text{.LO} lower bound
- \text{.UP} upper bound
- \text{.FX} fixed (lower bound=upper bound).

The variables (.L-values) keep their \textit{level} value from one solution to the next assignment. Unassigned upper bounds are set at plus infinity, non-initialized lower bounds at minus infinity. In direct assignments, variables should be referenced with their suffixes.

The initialization is at arbitrary values, in order to test the computational procedure. However, in empirical applications it is recommended to initialize the variables at their SAM-values.

*##########################################################*
* INITIALIZATION OR STARTING VALUES *
*##########################################################*

@Price block

*Income block

@Production block

@Expenditure block

*##########################################################*
\[ X.L(i) = X0(i) \]
\[ QGOVR.L(i) = QGOVR0(i) \]
\[ EXP.L(i) = E0(i) \]
\[ M.L(i) = M0(i) \]
\[ Q.L(i) = \beta(i) \cdot HEXP0/PX0(i) ; \]
\[ QR.L(i) = QR0(i) \]

*Income block*
\[ LY.L = LY0 \]
\[ KY.L = KY0 \]
\[ TY.L = TY0 \]
\[ adjL.L = 1 \]
\[ YENT.L = YENT0 \]
\[ YH.L = YH0 \]
\[ SAV.L = SAV0 \]
\[ DYH.L = DYH0 \]
\[ QINVM.L(i) = QINVM0(i) \]
\[ QINVR.L(i) = QINVR0(i) \]
\[ QINV.L(i) = QINV0(i) \]

** VARIABLE BOUNDS **

\[ PL.LO = 0.000001 ; \]
\[ PT.LO(ag) = 0.000001 ; \]
\[ PK.LO(i) = 0.000001 ; \]
\[ PR.LO(i) = 0.000001 ; \]
\[ PN.LO(i) = 0.000001 ; \]
\[ P.LO(i) = 0.000001 ; \]
\[ R.LO(i) = 0.000001 ; \]
\[ FX.LO(i) = 0.000001 ; \]
\[ QM.LO(i) \cdot (QM0(i) \neq 0) = 0.000001 ; \]
\[ QR.LO(i) \cdot (QR0(i) \neq 0) = 0.000001 ; \]
\[ Q.LO(i) \cdot (Q0(i) \neq 0) = 0.000001 ; \]
\[ VR.LO(i,j) \cdot (VR0(i,j) \neq 0) = 0.000001 ; \]
\[ VM.LO(i,j) \cdot (VM0(i,j) \neq 0) = 0.000001 ; \]
\[ V.LO(i,j) \cdot (V0(i,j) \neq 0) = 0.000001 ; \]

The follow statement uses GAMS-Options to reduce the amount of output and computer time assigned to solve the model. This is not recommended for beginners who may do better by getting more output from GAMS. Especially, for those having problems obtaining a “zero error message”. Iterlim, limrow, lincol and solprint, will limit the number of iterations, suppress the printing of equations, suppress the printing of columns, and suppress the list of the solution, respectively. Although this saves paper, we do not recommend it unless you understand your model very well and have your model running without error messages.

\[ \text{OPTIONS \ ITERLIM=5000, LIMROW=0, LIMCOL=0, SOLPRINT=OFF;} \]

**MODEL and SOLVE statements**

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A group of equations constitute a mathematical model. GAMS uses the statement `MODEL` to allow us to specify which equations should be considered as part of our mathematical model. In addition, we need to give a name to our model, i.e.; our Model is called OKLAHOMA.

```plaintext
*-- MODEL DEFINITION AND SOLVE STATEMENT

MODEL OKLAHOMA /ALL/;
```

We use in our example all the declared equations, if that would not be the case, instead of the word "ALL" we would have written each equation needed.

Equilibrium is found by minimizing the objective function `EQZ` that calculates the absolute sum of deviations (Slack variables). This process was introduced in section 4.2. (Click here to review section 4.2) The GAMS-statement to solve the mathematical program defined by the model OKLAHOMA with objective Z, using the MINOS5 non-linear programming algorithm NLP, reads as:

```plaintext
SOLVE OKLAHOMA MINIMIZING Z USING NLP;
```

**REPORTING VALIDATION OF THE MODEL**

When an equilibrium solution has been computed, the results are sorted in tabulation format. We define tables for commodity balances, prices, consumer budgets, etc.. These tables give the level of the endogenous variables of OKLAHOMA model. If they are correct, the values of these tables validate with those of our base year (SAM values). We call this process the validation of the model.

```plaintext
*-- SOLUTION DISPLAY STATEMENT
*-- SOLUTION VALUES OF ENDOGENOUS VARIABLES

PARAMETER VALID VARIABLES FOR THE VALIDATION OF THE MODEL;
VALID(i,"SLACK1") = SLACK.L(i);
VALID(i,"SLACK2") = SLACK2.L(i);
VALID(i,"PR") = PR.L(i);
VALID(i,"P") = P.L(i);
VALID(i,"PN") = PN.L(i);
VALID(i,"PK") = PK.L(i);
VALID(ag,"PT") = PT.L(ag);
VALID(i,"PX") = PX.L(i);
VALID(i,"PE") = PE0(i);
VALID(i,"X") = X.L(i);
VALID(i,"R") = R.L(i);
VALID(i,"EXP") = EXP.L(i);
VALID(i,"M") = M.L(i);
VALID(i,"VA") = VA.L(i);
VALID(i,"LAB") = LAB.L(i);
VALID(i,"CAP") = CAP.L(i);
VALID(ag,"LAND") = LAND.L(ag);
VALID(i,"TVR") = TVR.L(i);
VALID(i,"TVM") = TVM.L(i);
VALID(i,"TV") = TV.L(i);
VALID(i,"Q") = Q.L(i);
VALID(i,"QR") = QR.L(i);
```
VALID(i, "QM") = QM.L(i);
VALID(i, "QGOV") = QGOV.L(i);
VALID(i, "QGOVR") = QGOVR.L(i);
VALID(i, "QGOVM") = QGOVM.L(i);
VALID(i, "QINV") = QINV.L(i);
VALID(i, "QINVR") = QINVR.L(i);
VALID(i, "QINVM") = QINVM.L(i);
PARAMETER VALID2 - INTERMEDIATE USE MATRIX -;
VALID2(I, "AGR", "V") = V.L(I, "AGR");
VALID2(I, "MIN", "V") = V.L(I, "MIN");
VALID2(I, "MAN", "V") = V.L(I, "MAN");
VALID2(I, "SER", "V") = V.L(I, "SER");
VALID2(I, "AGR", "VR") = VR.L(I, "AGR");
VALID2(I, "MIN", "VR") = VR.L(I, "MIN");
VALID2(I, "MAN", "VR") = VR.L(I, "MAN");
VALID2(I, "SER", "VR") = VR.L(I, "SER");
VALID2(I, "AGR", "VM") = VM.L(I, "AGR");
VALID2(I, "MIN", "VM") = VM.L(I, "MIN");
VALID2(I, "MAN", "VM") = VM.L(I, "MAN");
VALID2(I, "SER", "VM") = VM.L(I, "SER");
PARAMETER VALID3 - VALIDATION OF THE MODEL -;
VALID3("OBJECTIVE") = Z.L;
VALID3("PL") = PL.L;
VALID3("LMIG") = LMIG.L;
VALID3("KMIG") = KMIG.L;
VALID3("TCAP") = TCAP.L;
VALID3("TLAB") = TLAB.L;
VALID3("LS") = LS.L;
VALID3("LMIG") = LMIG.L;
VALID3("ADJL") = ADJL.L;
VALID3("LY") = LY.L;
VALID3("ALY") = ALY.L;
VALID3("KY") = KY.L;
VALID3("TY") = TY.L;
VALID3("YENT") = YENT.L;
VALID3("RETENT") = RETENT.L;
VALID3("YH") = YH.L;
VALID3("PL") = PL.L;
VALID3("DYH") = DYH.L;
VALID3("HSAV") = HSAV.L;
VALID3("SADV") = SADV.L;
VALID3("INV") = INV.L;
VALID3("YGOV") = YGOV.L;
VALID3("GOVEXP") = GOVEXP.L;
VALID3("IBTX") = IBTX.L;
VALID3("GRP") = GRP.L;
VALID3("AHEMP") = AHEMP.L;

option decimals = 3;
DISPLAY VALID, VALID2, VALID3;

SIMULATION

Before starting a simulation run, one should specify the name of the scenario (here, simul1). The last step in preparing the model is to define the index sets and parameters for reporting. We define post-equilibrium variables that we use in constructing indexes for the relevant variables.

*######## SIMULATION ############*
PE0(i)=1.1;
model simul1 /all/;
solve simul1 minimizing z using nlp;
OPTION SOLPRINT=OFF;

*-- SOLUTION DISPLAY STATEMENT
*-- SOLUTION VALUES OF ENDOGENOUS VARIABLES

PARAMETER PRICES MARKET CLEARING PRICES;
PRICES(i,"SLACK1") = SLACK.L(i);
PRICES(i,"SLACK2") = SLACK2.L(i);
PRICES(i,"PR") = PR.L(i);
PRICES(i,"P") = P.L(i);
PRICES(i,"PN") = PN.L(i);
PRICES(i,"PK") = PK.L(i);
PRICES(i,"PT") = PT.L(i);
PRICES(i,"PX") = PX.L(i);
PRICES(i, "PE") = PE0(i);

PARAMETER PROD1 MARKET CLEARING PRODUCTION VARIABLES;
PROD1(i,"X") = X.L(i);
PROD1(i,"R") = R.L(i);
PROD1(i,"EXP") = EXP.L(i);
PROD1(i,"M") = M.L(i);
PROD1(i,"VA") = VA.L(i);
PROD1(i,"LAB") = LAB.L(i);
PROD1(i,"CAP") = CAP.L(i);
PROD1(i, "LAND") = LAND.L(i);

PARAMETER TRADE1 MARKET CLEARING PRODUCTION VARIABLES;
TRADE1(i,"TVR") = TVR.L(i);
TRADE1(i,"TVM") = TVM.L(i);
TRADE1(i,"TV") = TV.L(i);
TRADE1(i,"Q") = Q.L(i);
TRADE1(i,"QR") = QR.L(i);
TRADE1(i,"QM") = QM.L(i);
TRADE1(i,"QGOV") = QGOV.L(i);
TRADE1(i,"QGOVR") = QGOVR.L(i);
TRADE1(i,"QGOVM") = QGOVM.L(i);
TRADE1(i,"QINV") = QINV.L(i);
TRADE1(i,"QINVR") = QINVR.L(i);
TRADE1(i,"QINVM") = QINVM.L(i);

PARAMETER PRODUCT2 -PRODUCTION SYSTEMS VARIABLES-
PRODUCT2(I,"AGR","V")=V.L(I,"AGR");
PRODUCT2(I,"MIN","V")=V.L(I,"MIN");
PRODUCT2(I,"MAN","V")=V.L(I,"MAN");
PRODUCT2(I,"SER","V")=V.L(I,"SER");
PRODUCT2(I,"AGR","VR")=VR.L(I,"AGR");
PRODUCT2(I,"MIN","VR")=VR.L(I,"MIN");
PRODUCT2(I,"MAN","VR")=VR.L(I,"MAN");
PRODUCT2(I,"SER","VR")=VR.L(I,"SER");
PRODUCT2(I,"AGR","VM")=VM.L(I,"AGR");
PRODUCT2(I,"MIN","VM")=VM.L(I,"MIN");
PRODUCT2(I,"MAN","VM")=VM.L(I,"MAN");
PRODUCT2(I,"SER","VM")=VM.L(I,"SER");

PARAMETER OTHER1 MARKET CLEARING VALEUEES OF VARIABLES;
OTHER1("OBJECTIVE") = Z.L;
OTHER1("PL") = PL.L;
OTHER1("LMIG")=LMIG.L;
OTHER1("KMIG")=KMIG.L;
OTHER1("TCAP")=TCAP.L;
OTHER1("TLAB")=TLAB.L;
OTHER1("LS")=LS.L;
OTHER1("LMIG")=LMIG.L;
OTHER1("ADJL")=ADJL.L;
OTHER1("LY")=LY.L;
OTHER1("ALY")=ALY.L;
OTHER1("KY")=KY.L;
OTHER1("TY")=TY.L;
OTHER1("YENT")=YENT.L;
OTHER1("RENT")=RENTENT.L;
OTHER1("YH")=YH.L;
OTHER1("PL")=PL.L;
OTHER1("DYH")=DYH.L;
OTHER1("HSAV")=HSAV.L;
OTHER1("SAV")=SAV.L;
OTHER1("INV")=INV.L;
OTHER1("YGOV")=YGOV.L;
OTHER1("GOVEXP")=GOVEXP.L;
OTHER1("IBTX")=IBTX.L;
OTHER1("GRF")=GRF.L;
OTHER1("AHEMP")=AHEXP.L;

option decimals=3;
DISPLAY PROD1, TRADE1, PRODUCT2;

OPTION DECIMALS = 8;
DISPLAY OTHER1, PRICES;

* Parameters AS INDEX WITH 1993=1.000
PARAMETERS
  * -- Price block
    IPL  Wage rate index
    IPK(i)  Rent to capital index
    IPT(ag)  Land rent index
    IPR(i)  Regional price index
    IP(i)  Composite price index
    IPG  General composite price index
  * -- Production block
    IL(i)  Labor demand index
    ITL  Total labor demand index
    ILS  Labor supply index
    IK(i)  Capital demand index
    ITK  Total capital use index
    ITR  Total Land use index
    IT(ag)  Land demand index
    IVA(i)  Value added index
    IX(i)  Output index
    ITVA  Total Value added index
    ITX  Total Output index
    ITE  Total Export index
    ITR  Total Reg. supply index
    ITM  Total Import index
    IVM(j,i)  Imported interm demand index
    IVR(j,i)  Regional interm demand index
    IR(i)  Regional supply index
    IE(i)  Export index
    IM(i)  Import index
  * -- Income block
    IYH  Household (in the region) income index
    YHch  Change in hh income
    IDYH  Disposable income index
IHSAV Household saving index
IYGOV Government revenue index
NETGOV Net Revenue for government
IGRP Gross region product index
GRPch Change in Gross regional product
CapComp Capital Compensation
LandComp Land Compensation
Rconsup Resident angler consumer surplus loss
NRconsup NonResident angler consumer surplus loss

* -- Expenditure block
IAHEXP adj. Household expenditure index
IGOVEXP Government expenditure index
IQ(i) Commodity demand index
IQM(i) Imported commodity demand index
IQR(i) Regional commodity demand index

* -- EQUATIONS FOR CALCULATION OF INDEX WITH 1993=1.000

*### Price block
IPL = PL.L/PL0;
IPK(i) = PK.L(i)/PK0(i);
IPT(ag) = PT.L(ag)/PT0(ag);
IPR(i) = PR.L(i)/PR0(i);
IP(i) = P.L(i)/P0(i);
IPG = SUM(i, (PR.L(i)*R0(i)+PM0(i)*M0(i))/(R0(i)+M0(i)))/4;

*### Production block
IL(i) = LAB.L(i)/L0(i);
ITL = (SUM(i,LAB.L(i))+(LHHH0+LGOV0))/(SUM(i,L0(i))+LHHH0+LGOV0);
ILS = LS.L /LS0 ;
IK(i) = CAP.L(i)/K0(i);
ITK = SUM(i,PK.L(i)*CAP.L(i))/SUM(i,K0(i));
IT("Agr") = LAND.L("Agr")/T0("Agr");
ITT = PT.L("Agr")*LAND.L("Agr")/T0("Agr");
IVA(i) = VA.L(i)/Va0(i);
ITVA = SUM(i,VA.L(i))/SUM(i,Va0(i));
IX(i) = X.L(i)/X0(i);
ITX = SUM(i,X.L(i))/SUM(i,X0(i));
ITR = SUM(i,R.L(i))/SUM(i,R0(i));
ITM = SUM(i,M.L(i))/SUM(i,M0(i));
IVM(j,i)= VM.L(j,i)/VM0(j,i);
IVR(j,i) = VR.L(j,i)/VR0(j,i);
IR(i) = R.L(i)/R0(i);
IE(i) = EXP.L(i)/E0(i);
ITE = SUM(i,EXP.L(i))/SUM(i,E0(i));

*### Income block
IYH = YH.L /YH0 ;
IDYH = DYH.L /DYH0 ;
IHSAV = HSAV.L /HSAV0 ;
IGRP = GRP.L/GRP0;
GRPch = GRP.L-GRP0;

*###Expenditure block
IAHEXP = AHEXP.L /HEXP0 ;
IQ(i) = Q.L(i)/Q0(i);
IQM(i) = QM.L(i)/QM0(i);
IQR(i) = QR.L(i)/QR0(i);
IM(i) = M.L(i)/M0(i);
YHch = YH.L -adjL.L*YH0 ;
IYGOV = YGOV.L/YGOV0;
IGOVEXP = GOVEXP.L/GOVEXP0;
NETGOV = YGOV.L-GOVEXP0;
## SOLUTION VALUES OF INDEX

option decimals=5;

PARAMETER INDEX INDEXES FOR THE SIMULATION;
INDEX(I,"IPR")=IPR(I);
INDEX(I,"IX")=IX(I);
INDEX(I,"IE")=IE(I);
INDEX(I,"IL")=IL(I);
INDEX(I,"IK")=IK(I);
INDEX(I,"IPK")=IPK(I);
INDEX(ag,"IPT")=IPT(ag);
INDEX(ag,"IT")=IT(ag);
INDEX(I,"IVA")=IVA(I);
INDEX(I,"IR")=IR(I);
INDEX(I,"IM")=IM(I);
INDEX(I,"IQ")=IQ(I);
INDEX(I,"IQR")=IQR(I);
INDEX(I,"IQM")=IQM(I);
INDEX(I,"IPR")=IPR(I);
INDEX(I,"IPR")=IPR(I);

DISPLAY INDEX;
DISPLAY ITX,ITE,ITL,IPL,
    ITK,ITT,
    IGRP,GRPch,ITVA,ITR,ITM, YHch,
    IYH, IYGOV,IGOEXP,NETGOV,
    ILS,IDYH,IHSAV,IAHEXP,
    IVM,IVR;

DISPLAY IGRP,IPG,IYH,ITE,ITM;