KIEP Seminar
version 1.00

Computable General Equilibrium Modelling: Current Development and Its Usage

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Contents

1. What is a SAM?

1.1 Definition

■ Social accounting matrix (SAM) is a *matrix representation of the national accounts* (a la wikipedia)

- ▶ A SAM represents flows of all economic transactions that take place within an economy (regional or national).
- ▶ It is at the core, a matrix representation of the National Accounts for a given country, but can be extended to include non-national accounting flows, and created for whole regions or area.
- ▶ SAMs refer to a single year providing a static picture of the economy.

1.2 Special Features

- SAM's are square (columns equal rows) in the sense that all institutional agents are both buyers and sellers.
  - Institutions: Firms, Households, Government and 'ROW' sector
  - Columns represent buyers (expenditures) and rows represent sellers (receipts).
  - SAM's were created to identify all monetary flows from sources to recipients, within a disaggregated national account.

■ Typical SAM

	Expenditures			
Receipts		Endogenous	Exogenous	Total
	Endogenous	S_{nn}	S_{nx}	Y_n
	Exogenous	S_{xn}	S_{xx}	Y_x
	Total	Y_n'	Y_x'	

$$\begin{pmatrix} Y_n \\ Y_x \end{pmatrix} = \begin{pmatrix} A_{nn} & A_{nx} \\ A_{xn} & A_{xx} \end{pmatrix} \begin{pmatrix} Y_n \\ Y_x \end{pmatrix}$$

$$Y_n = A_{nn} Y_n + A_{nx} Y_x = (I - A_{nn})^{-1} A_{nx} Y_x = M_{nn} x_n$$

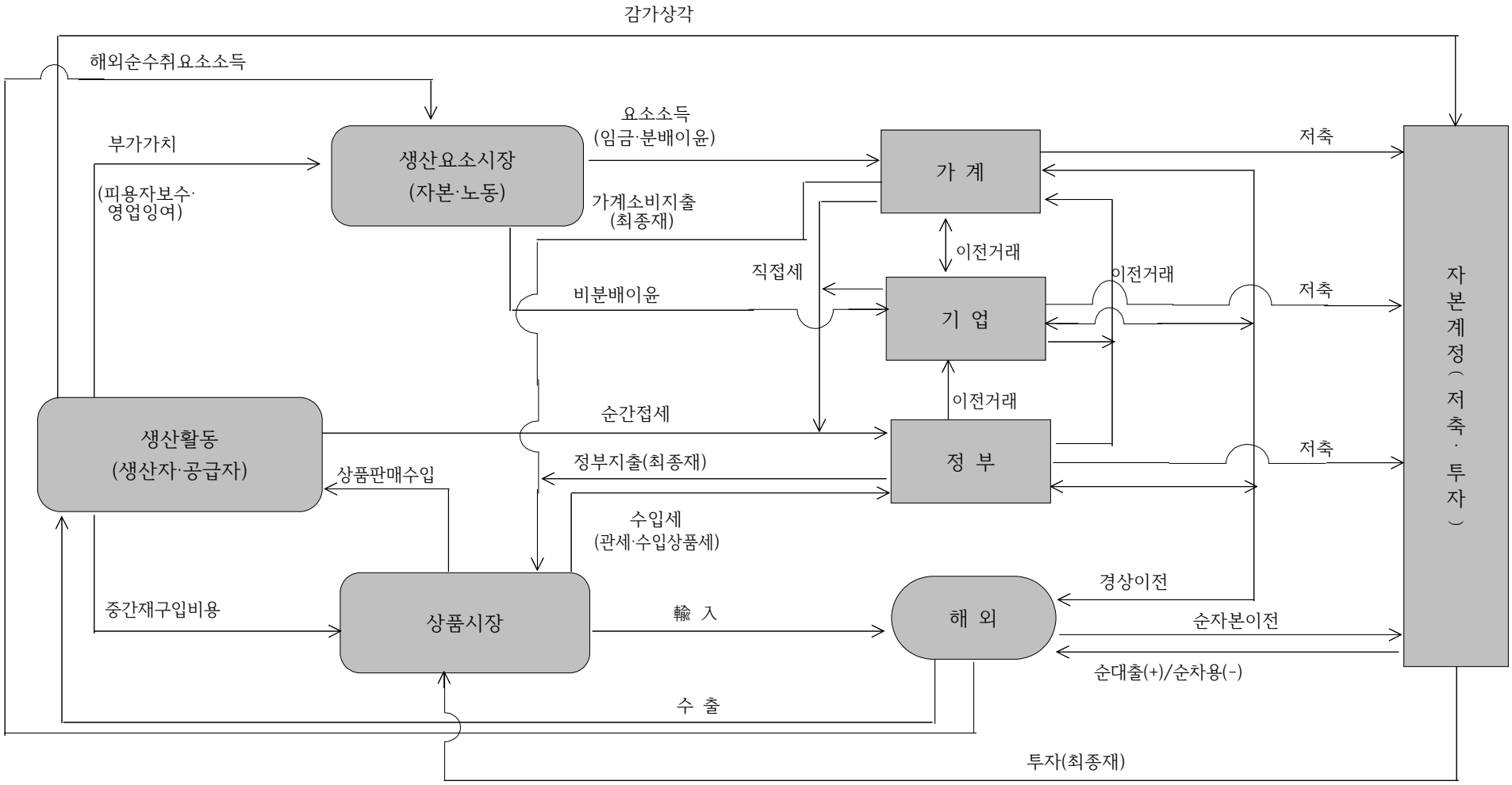
where $M_{nn} = (I - A_{nn})^{-1}$ is SAM multiplier matrix, $x_n \equiv A_{nx} Y_x$ exogenous injection, and I is an identity matrix

1.3 Example: Open Economy SAM

	Firm	Household	Govern-ment	Rest of Economy	Net Investment	Total (Received)
Firm		C	G_F	$(X-M)_K$	I	$C+G_F+(X-M)_K+I$
Household	W		G_H	$(X-M)_C$		$W+G_H+(X-M)_C$
Government	T_F	T_H				T_F+T_H
Rest of Economy	$(X-M)_K$	$(X-M)_C$				$(X-M)_K+(X-M)_C$
Net Investment		S_H	S_G			S_H+S_G
Total (Expended)	$W+T_F+(X-M)_K$	$C+T_H+(X-M)_C+S_H$	$G_F+G_H+S_G$	$(X-M)_C+(X-M)_K$	I	

Abbreviations: Capital letters: Taxes, Wages, iMports, eXports, Savings, Investment, Consumption, Government Transfer
Subscripts: Firms, Households, Government, Consumption Goods, K: Capital Goods

Circular Flows of an Economy



Source: Noh and Nam (2006), p. 10.

Illustration: Korean SAM (2000)

支出 / 收入	①생산활동	②상 품	③노동요소	④자본요소	⑤가 계	⑥기 업	⑦정 부	⑧자본계정	⑨해외부문	⑩오차 및 조정	합 계
① 생산활동		**7** 1,155,961.312							**38** 236,966.459		**46** 1,392,927.771
② 상 품	**1** 793,282.638				**18**[2] 352,370.988		**29**[3] 61,653.029	**35** 188,442.919			**47** 1,395,749.574
③ 노동요소	**2** 267,134.362								**(39)** 695.500		**(48)** 267,829.862
④ 자본요소	**3** 194,086.845								**(40)** 6,954.400		**(49)** 201,041.245
⑤ 가 계			**(11)** 267,189.662	**(14)** 82,917.800		**(24)** 25,914.400	**(30)** 10,928.700		**(41)** 7,242.300	**<A3>** 34,681.926	**(50)** 428,874.788
⑥ 기 업				**(15)** 108,609.145	**(19)** 7,787.600		**(31)** 59.200		**(42)** 0		**(51)** 116,455.945
⑦ 정 부	**4** 51,319.297	**8** 19,446.638			**(20)** 25,441.700	**(25)** 19,469.600			**(43)** 53.100	**<A4>** 16,258.494	**(52)** 131,988.829
⑧ 자본계정[10]	**5** 87,104.629				**(21)** 37,440.700	**(26)** 14,771.700	**(32)** 58,774.400		**(44)** 680.900	**<A5>** 5,346.390	**(53)** 204,118.719
⑨ 해외부문		**9** 220,341.624	**(12)** 640.200	**(16)** 9,514.300	**(22)** 5,833.800	**(27)** 244.100	**(33)** 573.500	**(36)** 15,675.800			**(54)** 252,823.324
⑩ 오차 및 조정						**<A1>** 56,056.145			**<A2>** 230.665		**<A7>** 56,286.810
합 계	**6** 1,392,927.771	**10** 1,395,749.574	**(13)** 267,829.862	**(17)** 201,041.245	**(23)** 428,874.788	**(28)** 116,455.945	**(34)** 131,988.829	**(37)** 204,118.719	**(45)** 252,823.324	**<A6>** 56,286.810	

주 1) 각 셀의 상단 숫자는 해당 셀을 정의하기 위한 번호를, 하단 숫자는 해당 셀의 실제 금액을 표시
2) 민간소비지출은 「산업연관표」의 정의에 따라 최종지출만을 포함하기 때문에 정부 및 해외 등에 대한 이전지출은 제외된 금액임
3) 정부소비지출은 「산업연관표」의 정의에 따라 정부가 공급하는 '공공행정 및 국방', '교육 및 보건', '사회 및 기타서비스'의 각 산출액에서 타 부문에 대한 서비스 판매액 (수업료, 시설사용자로부터 받는 수입 등)을 차감한 정부의 자가 소비지출액을 의미

1.4 History of SAM

- SAM's were originally developed at the "Cambridge Growth Project" in Cambridge, UK, which developed the first SAM in 1962 (Stone and Brown 1962).
  - They were built as a matrix representation of the National Account, and came to the World Bank with Graham Pyatt in the 1960s (Pyatt had worked for Richard Stone at the Cambridge Growth Project).
  - Pyatt left Cambridge and "developed SAMs, mainly at the World Bank", becoming together with Erik Thorbecke, the leading proponents and developers of SAMs

- "By the early 1980s, CGE models were heavily ensconced as the approach of the World Bank for development analysis.
- Social Accounting Matrices (SAMs) were similarly a mainstay of Bank analysis, which had been adopted as a presentational device by the CGE modelers" (Mitra-Kahn 2008: 23)

■ SAMs form the backbone of Computable general equilibrium (CGE) Models, various types of empirical multiplier models, and the Input-output model.

■ Appropriately formatted SAMs depict the spending patterns of an economy, as with IMPLAN and RIMS II data, and can be used in economic impact analysis.

2. How to Compile SAM?

2.1 History (in Practical Point of View)

- Francois Quesnay (1758), Tableau Economique
- Leon Warlas (1874), General Equilibrium Model
- Wassily Leontief (1936), Input-Output Table
- UN, 1968 System of National Accounts (1968 SNA)
- UN, 1993 System of National Accounts (1993 SNA)
- UN, 2008 System of National Accounts (2008 SNA)

■ Useful SAM Manuals in Korean

- Shin (2001), BOK Research Department - *Obsolete*
- Noh and Nam (2006), BOK IMER WP - Better than Shin, but needs some updates for 2008 SNA

2.3 Top-Down Approach

- Assemble Macro data first, and then add micro structures later
  - Requires vast amount of data: Input-Output Tables, National Income Accounts, Balance of Payments, Household Surveys, Survey on Labor Force Participation, etc.
- Steps 1-2-3
  - First, combines IOT and NIA data
  - Second, add some microeconomic aspects of income and expenditures by sub-groups
- Balancing SAM is always a big problem (to be covered later)
  - RAS, Entropy, Cross-Entropy, etc.

3. Macro SAM and Micro SAM

3.1 Macro SAM

	Activity	Commodity	Labor	Capital	Household/ Firm	Govern-ment	Capital Account	ROW	Total
Activity		Domestic Supply						Exports	
Commodity	Intermed. Demand				*Hous. Consump.*	Govt. Expend.	Investment		
Labor	*Employee's Compen.*								
Capital	Operating Surplus								
Household/ Firm									
Govern-ment	Indirect Tax (Net)	Import Tax							
Capital Account	Deprec.								
ROW		Imports							
Total									

3.2 Micro SAM

- Requires detailed classification of several cells
  - Activity and Commodity (often assumes 1-to-1 correspondence)
  - Households's Income/Expenditures
- How to disaggregate Cells in macro SAM? For example, Households can be decomposed by the income deciles, or by types of jobs of the household heads, or by regional aspects
- Likewise, Firms can be decomposed by the sales volume or by the size of employees, etc.
  - Refer Noh and Nam (2006), pp. 19-24.

3.3 How to Balance the SAM?

- There are several techniques available for Balancing SAM
  - Introducing 'Errors and Omissions' account is the WORST! (Noh and Nam, 2006)
  - RAS method is the second worst method (for illustration, see D. Shin's textbook on international trade, in Korean)
  - Cross-Entropy is the most widely used in the real-life analysis (Cattaneo, El-Said, *et al.*)
- What is the consequence of NOT Balancing?
  - The model lacks internal consistency, and thus provides us very limited implications.

4. SAM for CGE Modelling

4.1 SAM is the backbone of CGE Modelling

- It describes a benchmark equilibrium of the economy
  - We need to be very careful in determining the benchmark year.
- The first application of CGE Modeling in the economic science dates back to the late 1970s
  - Check the files in the GAMS Library for the Korean economy
  - The database used for the model economy is based on the 1963 Input-Output Table of the Korean Economy

5. Implementing of SAM in GAMS/Gempack

5.1 SAM in GAMS (General Algebraic Modeling System)

■ What is GAMS? homepage: http://www.gams.com

- ▶ GAMS was originally developed by World Bank in 1970's for the purpose of developing analytical tool for development economics
- ▶ In 1980s, it became private (i.e., commercial) software.
- ▶ Nowadays, it is the most popular analytical tools in various fields of academia, as well as in economics

■ Documentations GAMS

- ▶ GAMS Manual by Bruce McCarl
- ▶ Other course materials available, such as the one in EcoMod

■ GAMS code for Demonstration: There are several ways of implementing SAM in GAMS

- ▶ Directly input SAM data in the code (typical for the novice)
- ▶ Read data directly from Excel
- ▶ Use GDX utility

5.2 Demonstration of the Korean Economy in GAMS

$Title General Equilibrium Model for Korea (KORCGE,SEQ=100)

$Ontext

This mini equilibrium model of korea for the year 1963 is used to illustrate the basic use of CGE models. This version follows closely Chapter 11 of the reference.

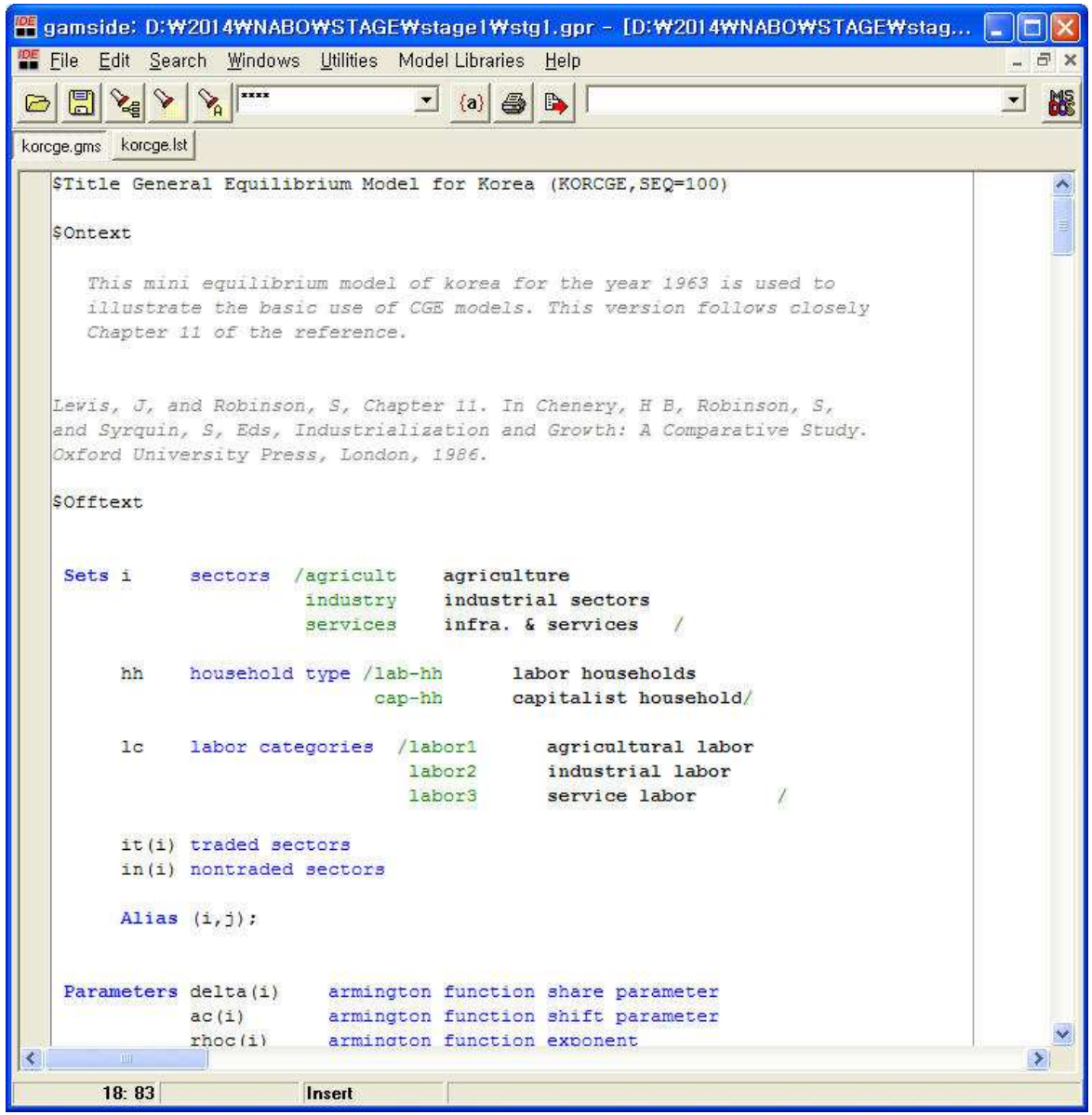
Lewis, J, and Robinson, S, Chapter 11. In Chenery, H B, Robinson, S, and Syrquin, S, Eds, *Industrialization and Growth: A Comparative Study*. Oxford University Press, London, 1986.

$Offtext

Note: See Appendix.

▶ provide some explanation of the sample library (if time allows)

5.3 Screen shot of GAMS



5.4 SAM in GEMPack (General Equilibrium Modeling Package)

■ Gempack is an alternative software for CGE modelling

- ▶ Homepage: http://www.copsmodels.com in Victoria University
- ▶ It is based upon Lief Johansen's so-called "small-change approach."
- ▶ It uses initial values and the percentage changes in order to solve the systems of non-linear equations

■ Minimal is a good starting point.

- ▶ Minimal model by Professor Mark Horridge (downloadable from http://www.copsmodels.com/minimal.htm)
- ▶ Software and Use manual

Any documentations in Korean?

- Korean version of Minimal Manual translated by Korea Gempack User Group (KGUG) will be available in June 2014.
- Korean version of MINIMAL is under development and will be released by October 2014.

Gempack requires Database in Head Array Format (HAR)

- HAR file is a binary format
- Illustration by example is very important in Gempack!

Demonstration of Miniature version of ORANI (if time permits)

5.5 Screen shot of HAR file

▶ Minimal Basedata

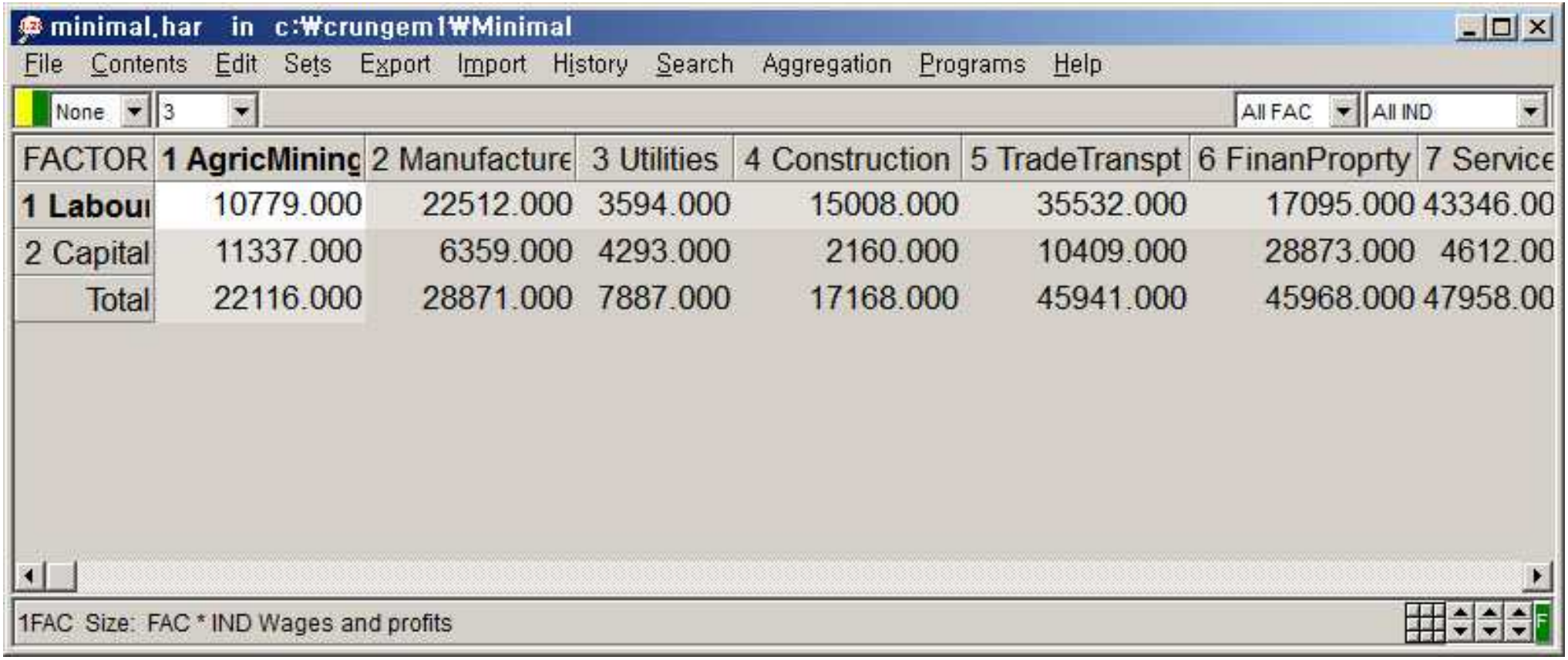

minimal.har in c:₩crungem1₩Minimal

File Contents Edit Sets Export Import History Search Aggregation Programs Help

	Header	Type	Dimension	Coeff	Total	Name
1	USE	RE	COM*SRC*USER	USE	524744	USE matrix
2	1FAC	RE	FAC*IND	FACTOR	215909	Wages and profits
3	0TAR	RE	COM	V0MTX	6363	Import tax revenue
4	1PTX	RE	IND	V1PTX	41783	Production tax revenue
5	ARM	RE	COM	SIGMA	14.0	Armington elasticities
6	P028	RE	IND	SIGMA1PRIM	3.50	Primary factor substitution elasticity
7	P018	RE	COM	EXP_ELAST	35.0	Export demand elasticities

Double-Click on an item to view it (or arrow keys + space bar)

▶ Wage and profits



References

Leontief, Wassily W., 1986, *Input-Output Economics. 2nd ed.*, New York: Oxford University Press.

Lewis, J, and Robinson, S, 1986, Chapter 11. In Chenery, H B, Robinson, S, and Syrquin, S, (Eds), *Industrialization and Growth: A Comparative Study*, Oxford University Press, London, 1986.

Mansur, A. and Whalley, J, 1984, “Numerical specification of applied general equilibrium models: Estimation, calibration, and data”, in Scarf, H.E., and Shoven, J.B. (Eds.), 1984, *Applied General Equilibrium analysis*, Cambridge, UK: Cambridge University Press.

Mitra-Kahn, Benjamin H., 2008, "Debunking the Myths of Computable General Equilibrium Models", SCEPA Working Paper 01-2008.

Pyatt and Round, 1985, "Social Accounting Matrices: A Basis for Planning", The World Bank.

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Labor Organization.

Robinson, S., Cattaneo, A., and El-Said, M., 2001, “Updating and Estimating a Social Accounting Matrix Using Cross Entropy Methods”, *Economic Systems Research* 13 (1), pp. 47-64.

Stone, R. and Brown, A., 1962, *A computable model for economic growth*, Cambridge, UK: Cambridge Growth Project.

International Input-Output Association, https://www.iioa.org/

MIG, Inc. (Formerly "Minnesota IMPLAN Group, Inc."), http://www.IMPLAN.com, http://en.wikipedia.org/wiki/IMPLAN

Noh and Nam, 2006, Income Re-distribution Effects of the Korean Economy: An Approach with Social Accounting Matrix, IMER Working Paper, Bank of Korea (in Korean).

Korean Gempack User Group, Minimal: A Simplified General Equilibrium Model, June 2014 (forthcoming).

Note: As of today, this part is under updating.

Appendix A. GAMS Code

```
$Title General Equilibrium Model for Korea (KORCGE,SEQ=100)

$Ontext

   This mini equilibrium model of korea for the year 1963 is used to
   illustrate the basic use of CGE models. This version follows closely
   Chapter 11 of the reference.

Lewis, J, and Robinson, S, Chapter 11. In Chenery, H B, Robinson, S,
and Syrquin, S, Eds, Industrialization and Growth: A Comparative Study.
Oxford University Press, London, 1986.

$Offtext

 Sets i     sectors  /agricult    agriculture
                      industry    industrial sectors
                      services    infra. & services   /

      hh    household type /lab-hh      labor households
                           cap-hh      capitalist household/

      lc    labor categories  /labor1      agricultural labor
                              labor2      industrial labor
                              labor3      service labor       /

      it(i) traded sectors
      in(i) nontraded sectors

      Alias (i,j);

 Parameters delta(i)    armington function share parameter
            ac(i)       armington function shift parameter
            rhoc(i)     armington function exponent
            rhot(i)     cet function exponent
            at(i)       cet function shift parameter
            gamma(i)    cet function share parameter
            ad(i)       production function shift parameter
            gles(i)     government consumption shares
            depr(i)     depreciation rates
            dstr(i)     ratio of inventory investment to gross output
            kio(i)      shares of investment by sector of destination
            te(i)       export duty rates
            itax(i)     indirect tax rates
            htax(hh)    income tax rate by household type
            pwm(i)      world market price of imports (in dollars)
            pwe(i)      world market price of exports (in dollars)
            tm(i)       tariff rates on imports
            pwts(i)     cpi weights ;

 htax("lab-hh  ") =   0.08910;
 htax("cap-hh  ") =   0.08910;

Table alphl(i,lc) labor share parameter in production function

              labor1    labor2    labor3

 agricult     0.38258   0.06740   0.00000
 industry     0.00000   0.53476   0.00000
 services     0.00000   0.16234   0.42326


Table io(i,j) input-output coefficients

            agricult  industry  services
```

```
agricult     0.12591    0.19834    0.01407
industry     0.10353    0.35524    0.18954
services     0.02358    0.11608    0.08390


Table imat(i,j) capital composition matrix

             agricult   industry   services

agricult     0.00000    0.00000    0.00000
industry     0.93076    0.93774    0.93080
services     0.06924    0.06226    0.06920


Table wdist(i,lc) wage proportionality factors

             labor1     labor2     labor3

agricult     1.00000    0.52780    0.00000
industry     0.00000    1.21879    0.00000
services     0.00000    1.11541    1.00000


Table cles(i,hh) private consumption shares

             lab-hh     cap-hh

agricult     0.47000    0.47000
industry     0.31999    0.31999
services     0.21001    0.21001


Table zz(*,i)  miscellaneous parameters

             agricult   industry   services

depr         0.00000    0.00000    0.00000
itax         0.01000    0.03920    0.05000
gles         0.02000    0.07000    0.91000
kio          0.13000    0.29000    0.58000
dstr         0.00000    0.00000    0.00000
te           0.00000    0.00000    0.00000
tm           0.10000    0.22751    0.08084
ad           0.61447    1.60111    0.52019
pwts         0.33263    0.43486    0.23251
pwm          0.90909    0.81466    0.92521
pwe          1.00000    1.00000    1.00000
sigc         2.00000    0.66000    0.40000
delta        0.24820    0.05111    0.00001
ac           1.59539    1.34652    1.01839
sigt         2.00000    2.00000    2.00000
gamma        0.86628    0.84602    0.82436
at           3.85424    3.51886    3.23592  ;

depr(i)    = zz("depr",i);
itax(i)    = zz("itax",i);
gles(i)    = zz("gles",i);
kio(i)     = zz("kio",i);
dstr(i)    = zz("dstr",i);
te(i)      = zz("te",i);
tm(i)      = zz("tm",i);
ad(i)      = zz("ad",i);
pwts(i)    = zz("pwts",i);
pwm(i)     = zz("pwm",i);
pwe(i)     = zz("pwe",i);
rhoc(i)    = (1/zz("sigc",i)) - 1 ;
delta(i)   = zz("delta",i);
ac(i)      = zz("ac",i);
rhot(i)    = (1/zz("sigt",i)) + 1;
gamma(i)   = zz("gamma",i);
```

```
 at(i)      = zz("at",i);

$Stitle model definition

 Variables

*prices block
   er        real exchange rate (won per dollar)
   pd(i)     domestic prices
   pm(i)     domestic price of imports
   pe(i)     domestic price of exports
   pk(i)     rate of capital rent by sector
   px(i)     average output price by sector
   p(i)      price of composite goods
   pva(i)    value added price by sector
   pr        import premium
   pindex    general price level
*production block
   x(i)      composite goods supply                    ('68 bill won)
   xd(i)     domestic output by sector                 ('68 bill won)
   xxd(i)    domestic sales                            ('68 bill won)
   e(i)      exports by sector                         ('68 bill won)
   m(i)      imports                                   ('68 bill won)
* factors block
   k(i)      capital stock by sector                   ('68 bill won)
   wa(lc)    average wage rate by labor category    (mill won pr person)
   ls(lc)    labor supply by labor category            (1000 persons)
   l(i,lc)   employment by sector and labor category   (1000 persons)
*demand block
   int(i)    intermediates uses                        ('68 bill won)
   cd(i)     final demand for private consumption      ('68 bill won)
   gd(i)     final demand for government consumption   ('68 bill won)
   id(i)     final demand for productive investment    ('68 bill won)
   dst(i)    inventory investment by sector            ('68 bill won)
   y         private gdp                               (bill won)
   gr        government revenue                        (bill won)
   tariff    tariff revenue                            (bill won)
   indtax    indirect tax revenue                      (bill won)
   netsub    export duty revenue                       (bill won)
   gdtot     total volume of government consumption    ('68 bill won)
   hhsav     total household savings                   (bill won)
   govsav    government savings                        (bill won)
   deprecia  total depreciation expenditure            (bill won)
   invest    total investment                          (bill won)
   savings   total savings                             (bill won)
   mps(hh)   marginal propensity to save by household type
   fsav      foreign savings                           (bill dollars)
   dk(i)     volume of investment by sector of destination ('68 bill won)
   ypr       total premium income accruing to capitalists  (bill won)
   remit     net remittances from abroad               (bill dollars)
   fbor      net flow of foreign borrowing             (bill dollars)
   yh(hh)    total income by household type            (bill won)
   tothhtax  household tax revenue                     (bill won)
*welfare indicator for objective function
   omega     objective function variable               ('68 bill won);

 er.l       =    1.0000 ;
 pr.l       =    0.0000 ;
 pindex.l   =    1.0000 ;
 gr.l       =  194.0449 ;
 tariff.l   =   28.6572 ;
 indtax.l   =   65.2754 ;
 netsub.l   =    0.0000 ;
 gdtot.l    =  141.1519 ;
 hhsav.l    =   61.4089 ;
 govsav.l   =   52.8930 ;
 deprecia.l =    0.0000 ;
 savings.l  =  159.1419 ;
 invest.l   =  159.1419 ;
 fsav.l     =   39.1744 ;
```

```
fbor.l     =   58.7590 ;
remit.l    =    0.0000 ;
tothhtax.l =  100.1122 ;
y.l        = 1123.5941 ;

Table labres1(i,lc) summary matrix with sectoral employment results

            labor1    labor2    labor3

 agricult   2515.900   442.643     0.000
 industry      0.000   767.776     0.000
 services      0.000   355.568   948.100

Table labres2(*,lc) summary matrix with aggregate employment results

            labor1    labor2    labor3

 wa            0.074     0.140     0.152
 ls         2515.900  1565.987   948.100

Table hhres(*,hh) summary matrix with household results

            lab-hh    cap-hh

 yh         548.7478  574.8463
 mps          0.0600    0.0600
    ;

l.l(i,lc) =  labres1(i,lc);
ls.l(lc)  =  labres2("ls",lc);
wa.l(lc)  =  labres2("wa",lc);
mps.l(hh)  = hhres("mps",hh) ;
yh.l(hh)   = hhres("yh",hh) ;

Table sectres(*,i) summary matrix with sectoral results

            agricult  industry  services

pd            1.0000    1.0000    1.0000
pk            1.0000    1.0000    1.0000
pva           0.7370    0.2911    0.6625
x           711.6443  930.3509  497.4428
xd          657.3677  840.0500  515.4296
xxd         641.7037  812.2222  492.0307
e            15.6639   27.8278   23.3988
m            69.9406  118.1287    5.4120
k           657.5754  338.7076 1548.5192
int         256.6450  464.1656  156.2598
cd          452.1765  307.8561  202.0416
gd            2.8230    9.8806  128.4482
id            0.0000  148.4488   10.6931
dst           0.0000    0.0000    0.0000
dk           20.6884   46.1511   92.3023
pm            1.0000    1.0000    1.0000
pe            1.0000    1.0000    1.0000
px            1.0000    1.0000    1.0000
p             1.0000    1.0000    1.0000
    ;

pd.l(i)  = sectres("pd",i) ;
pm.l(i)  = sectres("pm",i) ;
pe.l(i)  = sectres("pe",i) ;
pk.l(i)  = sectres("pk",i) ;
px.l(i)  = sectres("px",i) ;
p.l(i)   = sectres("p",i) ;
pva.l(i) = sectres("pva",i) ;
x.l(i)   = sectres("x",i) ;
xd.l(i)  = sectres("xd",i) ;
xxd.l(i) = sectres("xxd",i) ;
e.l(i)   = sectres("e",i) ;
```

```
 m.l(i)   = sectres("m",i) ;
 k.l(i)   = sectres("k",i) ;
 int.l(i) = sectres("int",i) ;
 cd.l(i)  = sectres("cd",i) ;
 gd.l(i)  = sectres("gd",i) ;
 id.l(i)  = sectres("id",i) ;
 dst.l(i) = sectres("dst",i) ;
 dk.l(i)  = sectres("dk",i) ;

 it(i) = yes$( e.l(i) or m.l(i) ) ;
 in(i) = not it(i) ;

 k.fx(i)   = k.l(i) ;
 m.fx(in) = 0; e.fx(in) = 0;
 l.fx(i,lc)$( l.l(i,lc) eq 0 ) = 0 ;

 p.lo(i)  = .01 ; pd.lo(i) = .01 ; pm.lo(it) = .01 ;
 pk.lo(i) = .01 ; px.lo(i) = .01 ; x.lo(i)   = .01 ;
 xd.lo(i) = .01 ; m.lo(it) = .01 ; xxd.lo(it) = .01 ; wa.lo(lc) = .01 ;
 int.lo(i) = .01 ; y.lo = .01 ; e.lo(it) = .01 ;
 l.lo(i,lc)$( l.l(i,lc) ne 0 ) = .01 ;

$Stitle equation definitions

 Equations

*price block
   pmdef(i)         definition of domestic import prices
   pedef(i)         definition of domestic export prices
   absorption(i)    value of domestic sales
   sales(i)         value of domestic output
   actp(i)          definition of activity prices
   pkdef(i)         definition of capital goods price
   pindexdef        definition of general price level

*output block
   activity(i)      production function
   profitmax(i,lc)  first order condition for profit maximum
   lmequil(lc)      labor market equilibrium
   cet(i)           cet function
   esupply(i)       export supply
   armington(i)     composite good aggregation function
   costmin(i)       f.o.c. for cost minimization of composite good
   xxdsn(i)         domestic sales for nontraded sectors
   xsn(i)           composite good agg. for nontraded sectors

*demand block
   inteq(i)         total intermediate uses
   cdeq(i)          private consumption behavior
   dsteq(i)         inventory investment
   gdp              private gdp
   labory           total income accruing to labor
   capitaly         total income accruing to capital
   hhtaxdef         total household taxes collected by govt.
   gdeq             government consumption shares
   greq             government revenue
   tariffdef        tariff revenue
   premium          total import premium income
   indtaxdef        indirect taxes on domestic production
   netsubdef        export duties

*savings-investment block
   hhsaveq          household savings
   gruse            government savings
   depreq           depreciation expenditure
   totsav           total savings
   prodinv(i)       investment by sector of destination
   ieq(i)           investment by sector of origin

*balance of payments
```

```
   caeq            current account balance (bill dollars)

*market clearing
   equil(i)        goods market equilibrium

*objective function
   obj             objective function ;

*price block

 pmdef(it)..       pm(it) =e= pwm(it)*er*(1 + tm(it) + pr) ;

 pedef(it)..       pe(it) =e= pwe(it)*(1 + te(it))*er ;

 absorption(i)..   p(i)*x(i) =e= pd(i)*xxd(i) + (pm(i)*m(i))$it(i) ;

 sales(i)..        px(i)*xd(i) =e= pd(i)*xxd(i) + (pe(i)*e(i))$it(i) ;

 actp(i)..         px(i)*(1-itax(i)) =e= pva(i) + sum(j, io(j,i)*p(j) ) ;

 pkdef(i)..        pk(i) =e= sum(j, p(j)*imat(j,i) );

 pindexdef..       pindex =e= sum(i, pwts(i)*p(i) ) ;

*output and factors of production block

 activity(i)..     xd(i) =e= ad(i) * prod(lc$wdist(i,lc),
l(i,lc)**alphl(i,lc) )
                            *k(i)**(1 - sum(lc, alphl(i,lc)) ) ;

 profitmax(i,lc)$wdist(i,lc).. wa(lc)*wdist(i,lc)*l(i,lc) =e=
                                xd(i)*pva(i)*alphl(i,lc) ;

 lmequil(lc)..     sum(i, l(i,lc)) =e= ls(lc) ;

 cet(it)..         xd(it) =e= at(it)*( gamma(it)*e(it)**rhot(it) +
                   ( 1-gamma(it) )*xxd(it)**rhot(it) )**(1/rhot(it)) ;

 esupply(it)..     e(it)/xxd(it) =e= ( pe(it)/pd(it)*(1 -
gamma(it))/gamma(it) )
                                        **(1/(rhot(it)-1) ) ;

 armington(it)..   x(it) =e= ac(it)*(delta(it)*m(it)**(-rhoc(it)) +
                   (1-delta(it))*xxd(it)**(-rhoc(it)))**(-1/rhoc(it)) ;

 costmin(it)..     m(it)/xxd(it) =e= ( pd(it)/pm(it)*delta(it)/(1-delta(it))
)**
                                       (1/(1 + rhoc(it))) ;

 xxdsn(in)..       xxd(in) =e= xd(in) ;

 xsn(in)..         x(in) =e= xxd(in) ;


*demand block

 inteq(i)..        int(i) =e= sum(j, io(i,j)*xd(j) );

 dsteq(i)..        dst(i) =e= dstr(i)*xd(i) ;

 cdeq(i)..         p(i)*cd(i) =e= sum(hh, cles(i,hh)*(1-mps(hh))*yh(hh)
                                    *(1-htax(hh)) ) ;

 gdp..             y =e= sum(hh, yh(hh) ) ;

 labory..          yh("lab-hh") =e= sum(lc, wa(lc)*ls(lc) ) + remit*er ;

 capitaly..        yh("cap-hh") =e= sum(i, pva(i)*xd(i) ) - deprecia -
                              sum(lc, wa(lc)*ls(lc) ) + fbor*er + ypr ;
```

```
 hhsaveq..        hhsav =e= sum(hh, mps(hh)*yh(hh)*(1 - htax(hh))) ;

 greq..           gr =e= tariff - netsub + indtax +tothhtax ;

 gruse..          gr =e= sum(i, p(i)*gd(i)) + govsav ;

 gdeq(i)..        gd(i) =e= gles(i)*gdtot ;

 tariffdef..      tariff =e= sum(it, tm(it)*m(it)*pwm(it) )*er ;

 indtaxdef..      indtax =e= sum(i, itax(i)*px(i)*xd(i) );

 netsubdef..      netsub =e= sum(it, te(it)*e(it)*pwe(it) )*er ;

 premium..        ypr =e= sum(it, pwm(it)*m(it) )*er*pr ;

 hhtaxdef..       tothhtax =e= sum(hh, htax(hh)*yh(hh) ) ;

 depreq..         deprecia =e= sum(i, depr(i)*pk(i)*k(i) ) ;

 totsav..         savings =e= hhsav + govsav + deprecia + fsav*er ;

 prodinv(i)..     pk(i)*dk(i) =e= kio(i)*invest - kio(i)*sum(j, dst(j)*p(j))
;

 ieq(i)..         id(i) =e= sum(j, imat(i,j)*dk(j));

*balance of payments

 caeq..           sum(it, pwm(it)*m(it)) =e= sum(it, pwe(it)*e(it))
                                           +  fsav + remit + fbor ;
*market clearing

 equil(i)..       x(i) =e= int(i) + cd(i) + gd(i) + id(i) + dst(i) ;

*objective function

 obj..            omega =e= prod(i$cles(i,"lab-hh"),
                                        cd(i)**cles(i,"lab-hh")) ;

   er.fx = er.l ;
   fsav.fx = fsav.l ;
   remit.fx = remit.l ;
   fbor.fx = fbor.l ;

   pindex.fx = pindex.l ;

   mps.fx(hh) = mps.l(hh) ;
   gdtot.fx = gdtot.l ;

   ls.fx(lc) = ls.l(lc) ;

 Model model1 square base model / all / ;

 Solve model1 maximizing omega using nlp;
```