

Introduction to Computable General Equilibrium Model (CGE)

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Course Outline

- Overview of CGE
- An Introduction to the Structure of CGE
- **An Introduction to GAMS**
- Casting CGE models into GAMS
- Data for CGE Models & Calibration
- Incorporating a trade & a basic CGE application
- Evaluating impacts of policy changes and casting nested functions & a trade in GAMS
- Mixed Complementary Problems (MCP)

This Week's Road Map

- What is GAMS?
- Using GAMS
- Dissecting GAMS Formulation
- A user interface - GAMS IDE
 - ➔ steps to create and run programs
- Features of the GAMS IDE
- GAMS Documentation

What is GAMS?

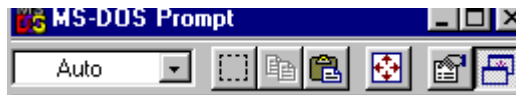
- **Generalized Algebraic Modeling System**
 - a language for setting up and solving mathematical programming optimization models
 - **all-in-one package** that allows one to
 - **specify the structure** of an optimization model
 - **specify and calculate** data that go into that model
 - **solve** that model
 - **conduct** report writing on a model
 - **perform** a comparative static analysis

Using GAMS

- Two approaches to using GAMS

- (1) Traditional method:

use a text editor set up the model then use DOS (or UNIX) command line instructions to find errors in and run the model



```
[scout]/tontoone/tasana/cge% gams allcge.gms|
```

- (2) GAMS IDE alternative:



A graphical interface to create, debug, edit and run GAMS files. We will use GAMS through the IDE for this class.

Formulation of a Simple Market Clearing

- Demand: $P \geq P_d = 6 - 0.3 \cdot Q_d$
- Supply: $P \leq P_s = 1 + 0.2 \cdot Q_s$
- Equilibrium: $Q_s \geq Q_d$ and $P, Q_s, Q_d \geq 0$

POSITIVE VARIABLE

```
P           Equilibrium price
Qd          Quantity demanded
Qs          Quantity supply      ;
```

EQUATION

```
DemandPrice      Demand equation
SupplyPrice      Supply equation
Qbalance         Equilibrium equation ;
```

```
DemandPrice..   P           =G= 6-0.3*Qd      ;
SupplyPrice..   1+0.2*Qs     =G= P           ;
Qbalance..      Qs          =G= Qd          ;
```

```
MODEL EQUIL     /DemandPrice.Qd
                SupplyPrice.Qs
                Qbalance.P / ;
```

```
OPTION MCP      = PATH      ;
```

```
SOLVE EQUIL using MCP      ;
```

Formulation of a Simple Market Clearing

Demand:

$$P \geq 6 - 0.3 \cdot Q_d$$

$$[P - (6 - 0.3 \cdot Q_d)] Q_d = 0$$

$$Q_d = 0 \text{ then } P > 6 - 0.3 \cdot Q_d$$

Supply:

$$P \leq 1 + 0.2 \cdot Q_s$$

$$[P - (1 + 0.2 \cdot Q_s)] Q_s = 0$$

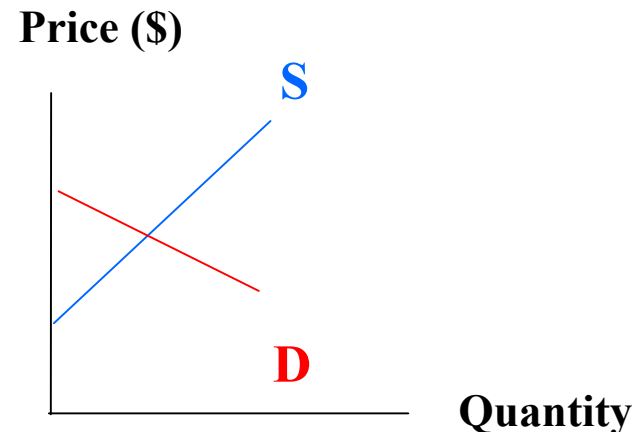
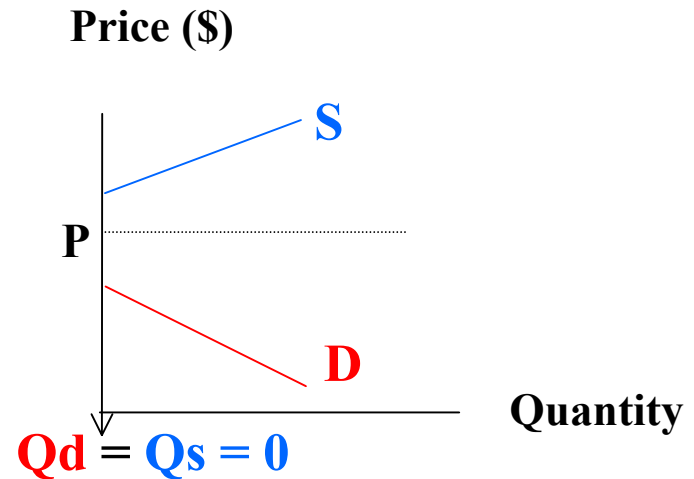
$$Q_s = 0 \text{ then } P < 1 + 0.2 \cdot Q_s$$

Equilibrium:

$$Q_s \geq Q_d$$

$$(Q_s - Q_d) P = 0$$

$$P = 0 \text{ then } Q_s > Q_d$$



Formulation of a Simple Market Clearing

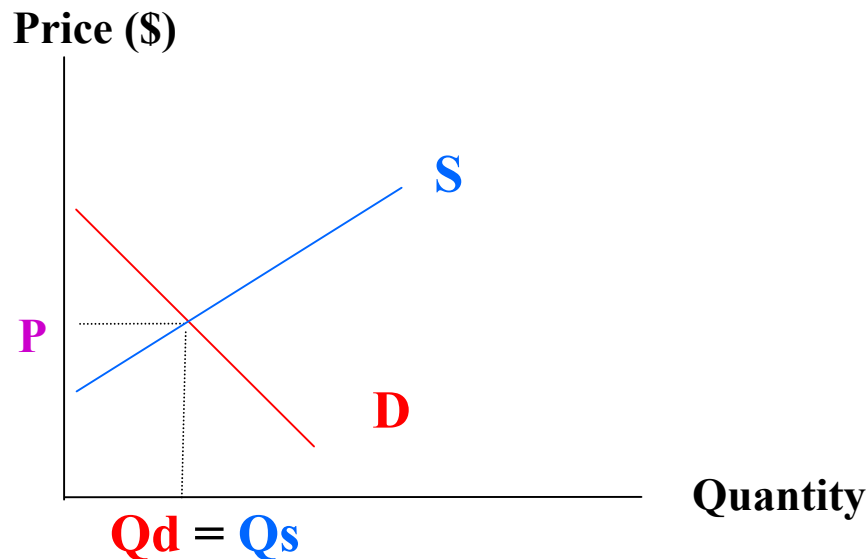
IF

$$Q_d > 0 \text{ then } P = 6 - 0.3 \cdot Q_d$$

$$Q_s > 0 \text{ then } P = 1 + 0.2 \cdot Q_s$$

$$P > 0 \text{ then } Q_s = Q_d$$

} Implies that $P_d = P_s = P$



GAMS Solution

■ Solution

		LOWER	LEVEL	UPPER	MARGINAL
----	EQU DemandPrice	6.000	6.000	+INF	10.000
----	EQU SupplyPrice	-1.000	-1.000	+INF	10.000
----	EQU Qbalance	.	.	+INF	3.000

		LOWER	LEVEL	UPPER	MARGINAL
----	VAR P	.	3.000	+INF	.
----	VAR Qd	.	10.000	+INF	.
----	VAR Qs	.	10.000	+INF	.

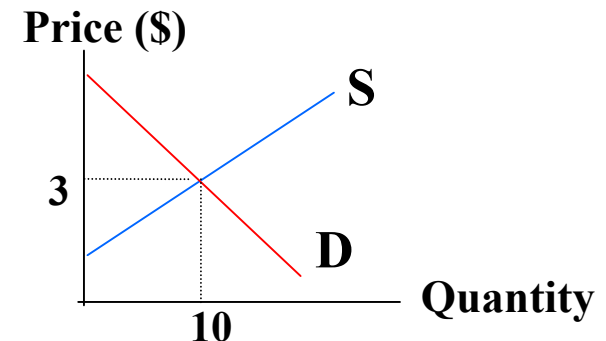
----	VARIABLE	P.L	=	3.000	Equilibrium price
	VARIABLE	Qd.L	=	10.000	Quantity demanded
	VARIABLE	Qs.L	=	10.000	Quantity supply

■ At Equilibrium:

$$P_d = P_s = P \Rightarrow P_d = 6 - 0.3 \cdot 10 = 3$$

$$P_s = 1 + 0.2 \cdot 10 = 3$$

$$Q_d = Q_s = 10$$



Dissecting GAMS

POSITIVE VARIABLE

```
P           Equilibrium price
Qd          Quantity demanded
Qs          Quantity supply      ;
```

EQUATION

```
DemandPrice      Demand equation
SupplyPrice      Supply equation
Qbalance         Equilibrium equation ;
```

```
DemandPrice..   P           =G= 6-0.3*Qd      ;
SupplyPrice..   1+0.2*Qs     =G= P           ;
Qbalance..      Qs          =G= Qd          ;
```

```
MODEL EQUIL     /DemandPrice.Qd
                  SupplyPrice.Qs
                  Qbalance.P / ;
```

```
OPTION MCP      = PATH      ;
SOLVE EQUIL     using MCP   ;
```

Dissecting GAMS – Variable naming

■ Variable Specification

GAMS requires variables in each problem to be identified. In the example, we have variables **P**, **Qd**, **Qs**

POSITIVE VARIABLE

P	Equilibrium price	
Qd	Quantity demanded	
Qs	Quantity supply	;

2 types of variables

VARIABLE

unrestricted variables

POSITIVE VARIABLE

restricted variables to be nonnegative

$$\mathbf{P} \geq \mathbf{0}$$

$$\mathbf{Qd} \geq \mathbf{0}$$

$$\mathbf{Qs} \geq \mathbf{0}$$

Dissecting GAMS – Equation naming

- **Equation Specification** consists of two parts.

(1) Naming equations:

GAMS requires the modeler name each equation, which is active in the model. In the example, the equations are named in the **EQUATION** line

EQUATION

```
DemandPrice  
SupplyPrice  
Qbalance
```

```
Demand equation  
Supply equation  
Equilibrium equation ;
```

Text comments

The name for each equation can be anything up to 31 characters.

Dissecting GAMS – Equation algebra

(2) Specifying algebraic structure:

: After naming equations, the exact algebraic structure of equations must be specified by using `..` notation.

DemandPrice <code>..</code>	P	<code>=G=</code>	$6 - 0.3 * Qd$;	P	<code>≥</code>	$6 - 0.3 * Qd$
SupplyPrice <code>..</code>	$1 + 0.2 * Qs$	<code>=G=</code>	P	;	P	<code>≤</code>	$1 + 0.2 * Qs$
Qbalance <code>..</code>	Qs	<code>=G=</code>	Qd	;	Qs	<code>≥</code>	Qd

This algebraic form involves use of a special syntax to tell the exact form of the equation that may actually be an inequality.

`=E=` indicates an equality constraint

`=L=` indicates a less than or equal to constraint

`=G=` indicates a greater than or equal to constraint

Dissecting GAMS – Model & complementarity

■ Model Specification

MODEL statement is used to identify models that will be solved. It involves 2 steps

: give name of the model (e.g. EQUIL)

: specify equations that will be included in the model in slashes / /

MCP = Mixed Complementary Problem

MCP uses ‘.’ as complementary

```
MODEL EQUIL      /DemandPrice.Qd  
                  SupplyPrice.Qs  
                  Qbalance.P / ;
```

```
MODEL EQUIL      /DemandPrice.Qd  
                  SupplyPrice.Qs / ;
```

Omitting Qbalance equation

Dissecting GAMS

■ Solve Specification

SOLVE causes GAMS to use a solver to **the model named (EQUIL)** immediately after the SOLVE statement.

```
SOLVE   EQUIL using MCP ;
```

MCP = Mixed Complementary Problem

That model must already have been defined in a **MODEL** statement.

```
MODEL EQUIL   /DemandPrice.Qd  
                SupplyPrice.Qs  
                Qbalance   .P / ;
```

Dissecting GAMS

■ ; Specification

GAMS requires to terminate each statement with a ; .

POSITIVE VARIABLE

```
P           Equilibrium price
Qd          Quantity demanded
Qs          Quantity supply ;
```

EQUATION

```
DemandPrice Demand equation
SupplyPrice  Supply equation
Qbalance     Equilibrium equation ;
```

```
DemandPrice.. P           =G= 6-0.3*Qd ;
SupplyPrice.. 1+0.2*Qs     =G= P       ;
Qbalance..    Qs          =G= Qd      ;
```

```
MODEL EQUIL /DemandPrice.Qd
              SupplyPrice.Qs
              Qbalance.P / ;
```

```
OPTION MCP = PATH ;
SOLVE EQUIL using MCP ;
```

;

is a very important part of the syntax. The omission often causes many syntax errors.

Dissecting GAMS – Finding errors

```
DemandPrice..   P           =G= 6-0.3*Qd
SupplyPrice..   1+0.2*Qs     =G= P
Qbalance..      Qs          =G= Qd
```

;

;

Error Messages

```
--- Starting compilation
--- SMALLMCP.GMS(14) 1 Mb 1 Error
*** Error 409 in C:\TASANA\685CGEPROJECT\SMALLMCP.GMS
    Unrecognizable item - skip to find a new statement
    looking for a ';' or a key word to get started again
--- SMALLMCP.GMS(22) 1 Mb 2 Errors
*** Error 257 in C:\TASANA\685CGEPROJECT\SMALLMCP.GMS
    Solve statement not checked because of previous errors
--- SMALLMCP.GMS(24) 1 Mb 5 Errors
*** Error 141 in C:\TASANA\685CGEPROJECT\SMALLMCP.GMS
    Symbol neither initialized nor assigned
    A wild shot: You may have spurious commas in the explanatory
    text of a declaration. Check symbol reference list.
```

GAMS IDE - Steps

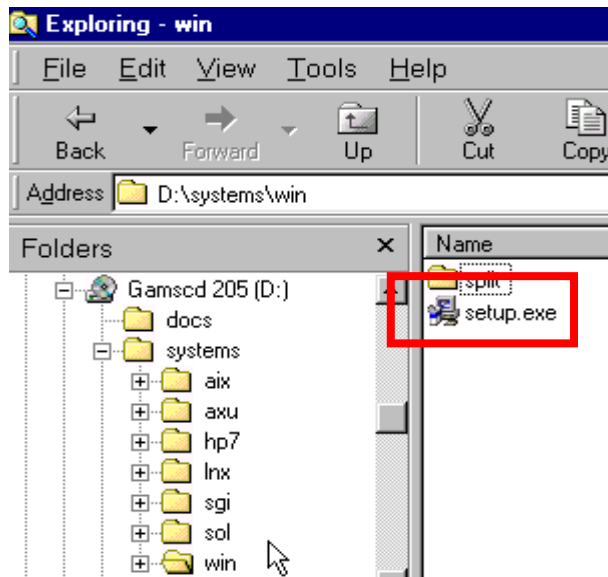
- Steps to using GAMS IDE
 1. Install GAMS and IDE
 2. Start the IDE
 3. Create and open files
 4. House keeping
 5. Run GAMS
 7. Navigate around outputs

GAMS IDE - Install from CD

1. Install GAMS and the IDE on your computer

The IDE is automatically installed when GAMS is installed. To install do the following steps

a. load the GAMS CD into your machine



b. start the installation using the Windows Explorer and go into the systems subdirectory called **win** then double click on **setup.exe**

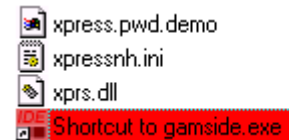
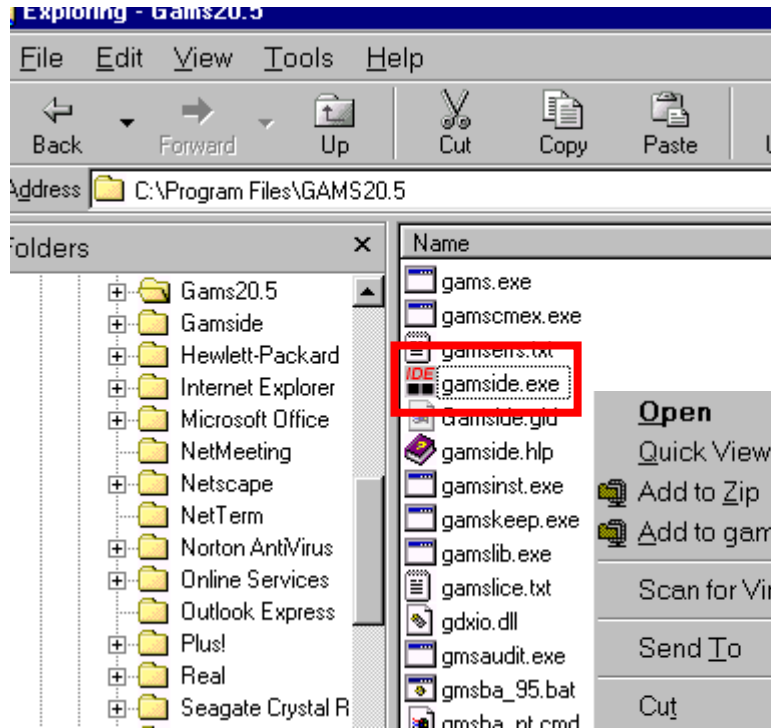
c. supply the location for a license (on your floppy)

GAMS IDE



- Create an icon

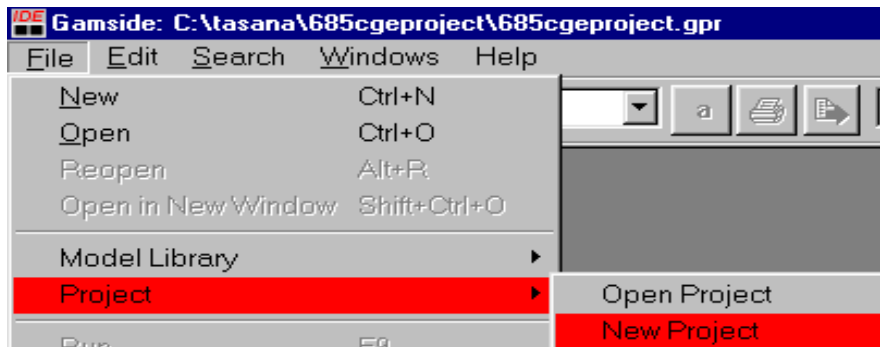
d. right click on gamside.exe in the GAMS system directory, choose “create shortcut” and drag the shortcut to your desktop



GAMS IDE - Start IDE

2. Start the IDE using it's icon

- a. double click the icon
- b. create a directory for your work by opening the File menu and select Project and New project

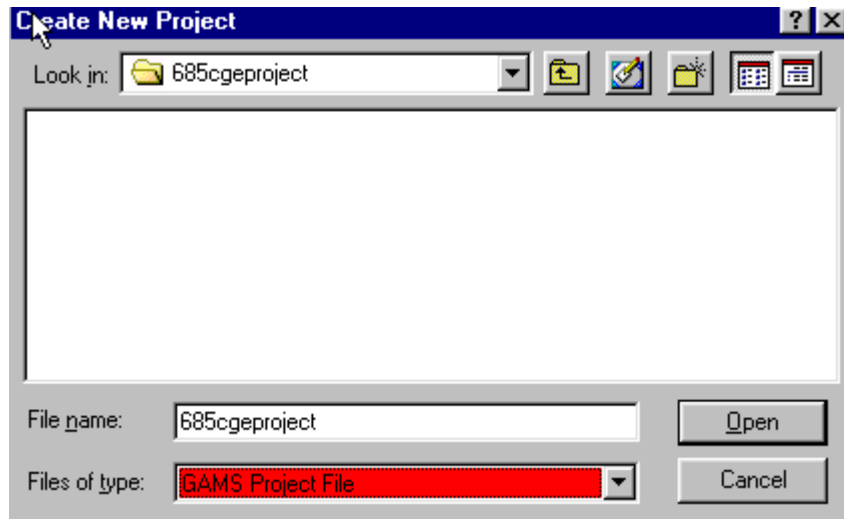


The IDE uses a “Project” file for two purposes.

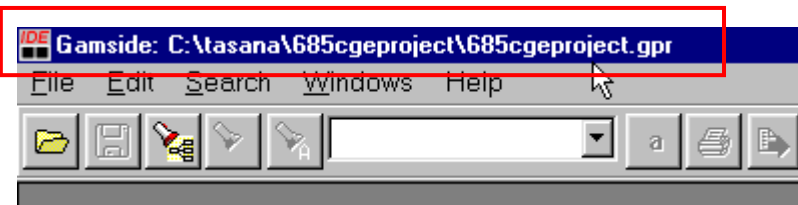
- : to determine where all saved files are placed and where GAMS looks for files when executing
- : to save file names and program options associated with the effort.

GAMS IDE - Create project

c. define project name and location. All files associated with this project will be saved here



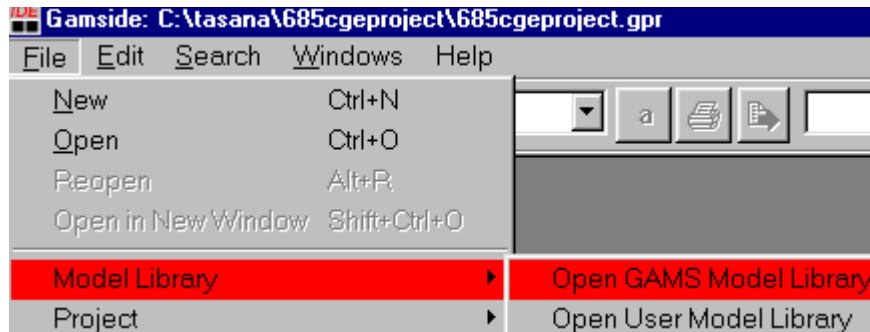
In the “**File name**” area type in a name for the project file you wish to use. This defines the directory where your files are located.



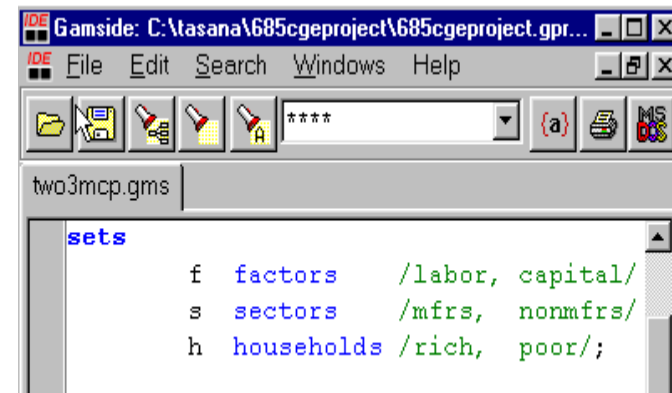
GAMS IDE - How to open library files

3. Open existing files

a. from the model library

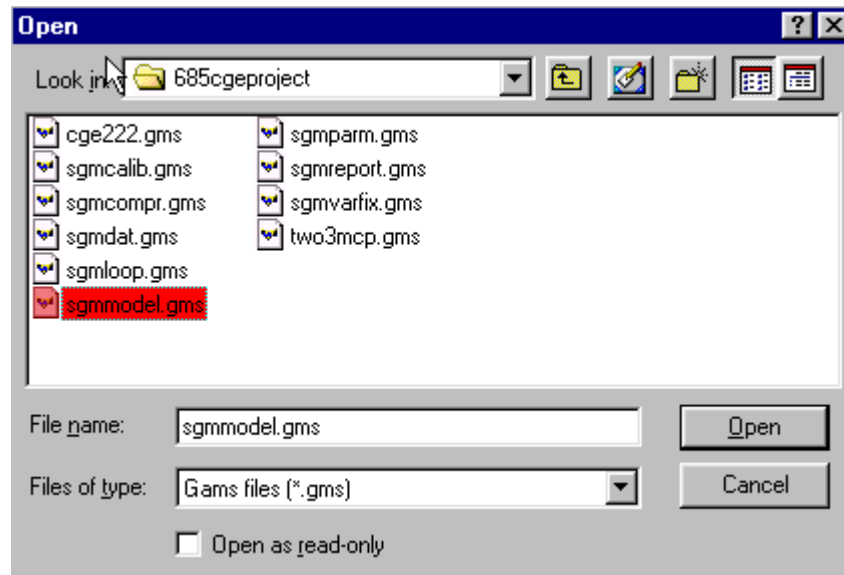
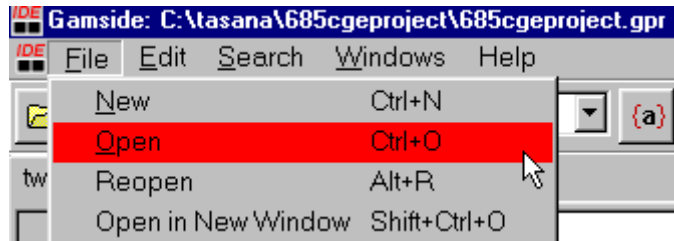


GAMS Model Library Version 11.0				
Search two3				
Name +	Application Area	Type	Contributor	Description
TSP42	Recreational Models	MIP	Dantzig, G B	TSP solution wit
TURKEY	Agricultural Economics	NLP	Le-Si, V	Turkey Agricult.
TURKPOW	Energy Economics	LP	Turvey, R	Turkey Power P
TWO3MCP	Applied General Equilibrium	MCP	Shoven, J	Simple 2 x 2 x 2
UIMP	Management Science and OR	LP	Ellison, E F	UIMP - Producti
UNSTMGE	Applied General Equilibrium	MPSGE	Scarf, H	Globally Unstabl



GAMS IDE - Open your files

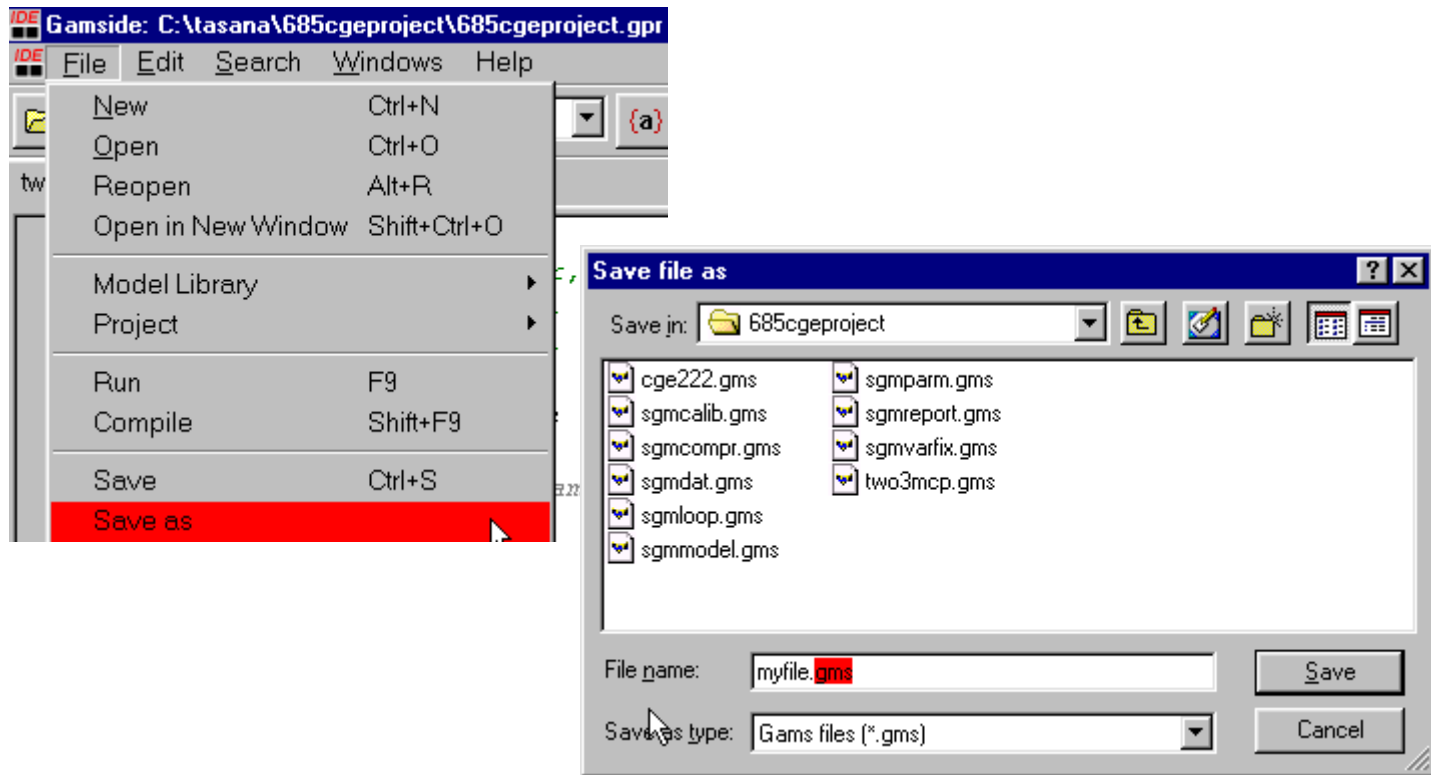
b. from your directory



GAMS IDE - Rename a file

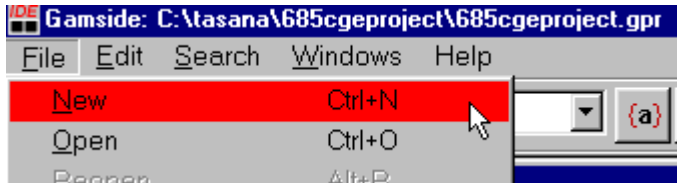
4. Create new files

a. open existing files and with save as dialogue from file menu change it's name.

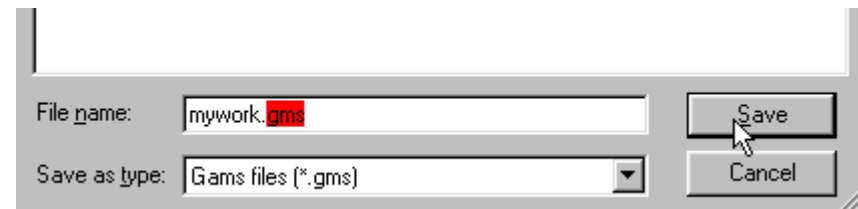
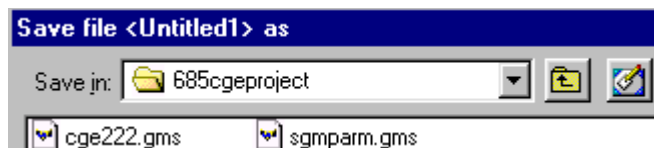
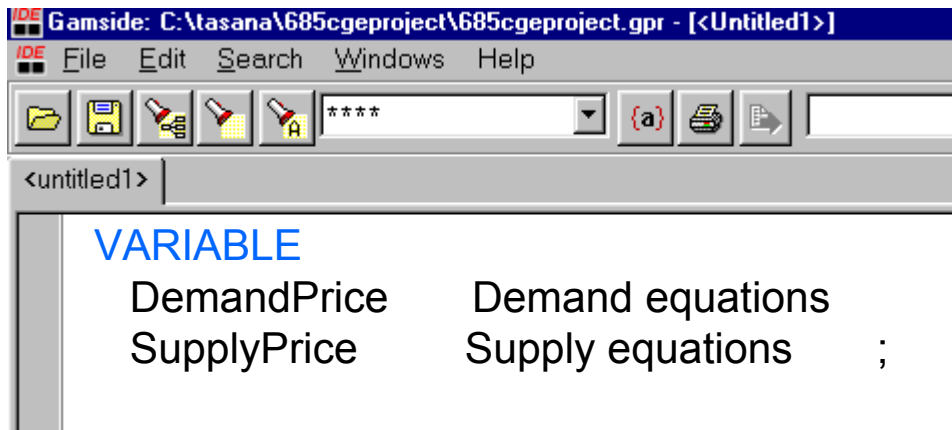


GAMS IDE - Make a file

b. open the file menu and use the new option.



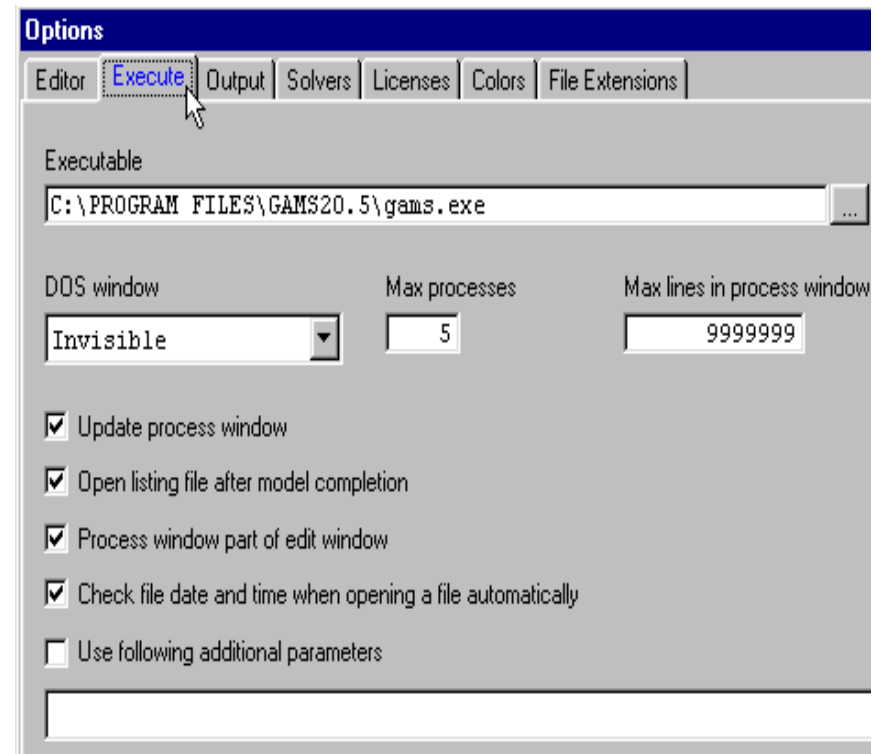
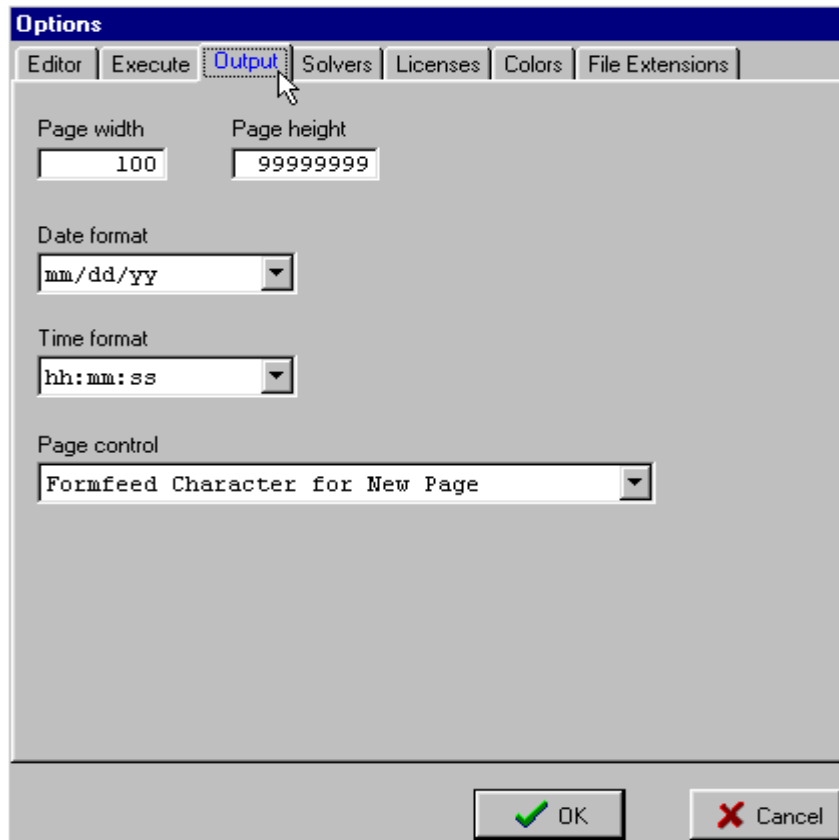
You will then get a file called **untitled** with an empty screen that you can create (type) your own program.



GAMS IDE - Fixes display

5. Do a little housekeeping

: use the options dialog under File to set the output page length to 9999 and under the execute dialog check the box update process window



GAMS IDE - Fixes display

Options

Editor | Execute | Output | Solvers | Licenses | Colors | File Extensions

Font: ... Font size:

Auto indentation Show hints

Syntax colors

Highlight URLs

Show special characters

Files to save before run or compile:

End of Line comments:

Maximum lines for syntax colors: Right margin position:

GAMS file extensions:

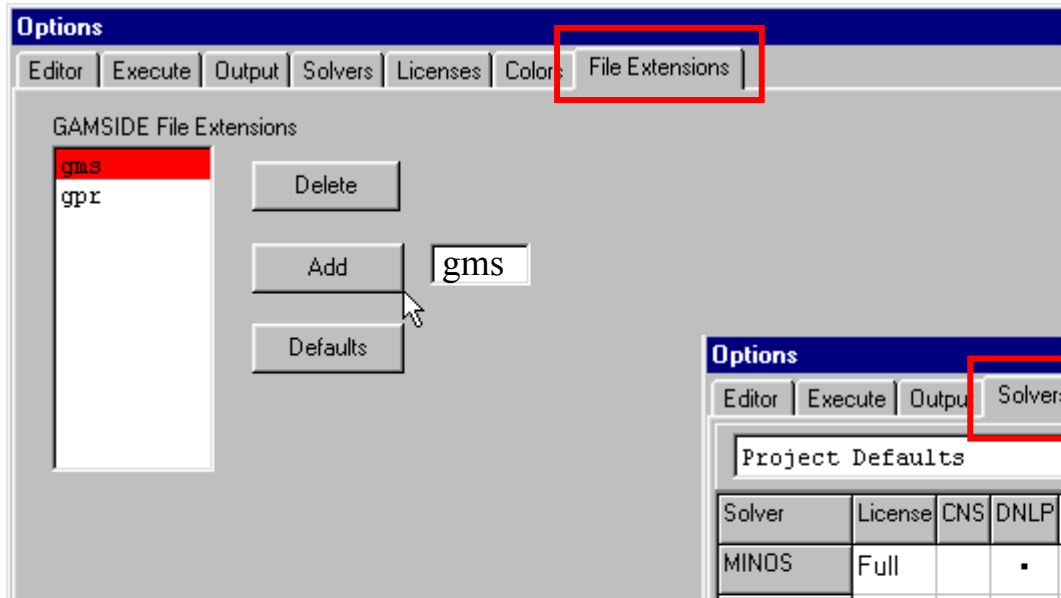
Tab key action: Tab size (read): Tab stops (edit):

OK Cancel

GAMS IDE - Choose solvers

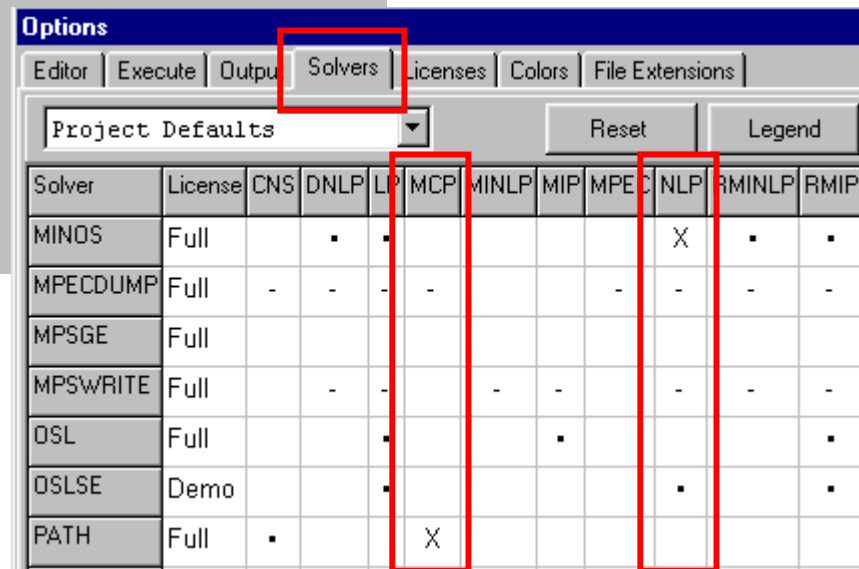
5. Do a little housekeeping (con't)

: make IDE the *.gms file processor



: set up solvers

e.g. if NLP using MINOS
if LP using CPLEX
if MCP using PATH



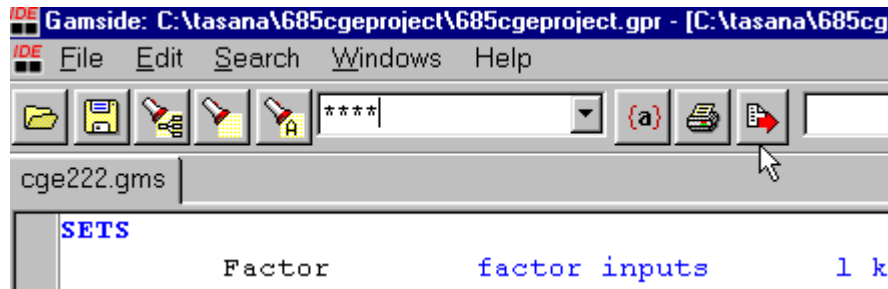
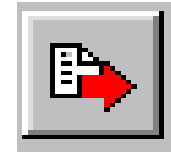
The screenshot shows the 'Options' dialog box with the 'Solvers' tab selected. The 'Project Defaults' dropdown is set to 'Project Defaults'. The table below shows the solver configuration for various solvers. The 'MCP' and 'NLP' columns are highlighted with red boxes.

Solver	License	CNS	DNLP	LP	MCP	MINLP	MIP	MPEC	NLP	RMINLP	RMIP
MINOS	Full		•	•					X	•	•
MPECDUMP	Full	-	-	-	-			-	-	-	-
MPSGE	Full										
MPSWRITE	Full		-	-		-	-		-	-	-
OSL	Full				•		•				•
OSLSE	Demo				•				•		•
PATH	Full	•			X						

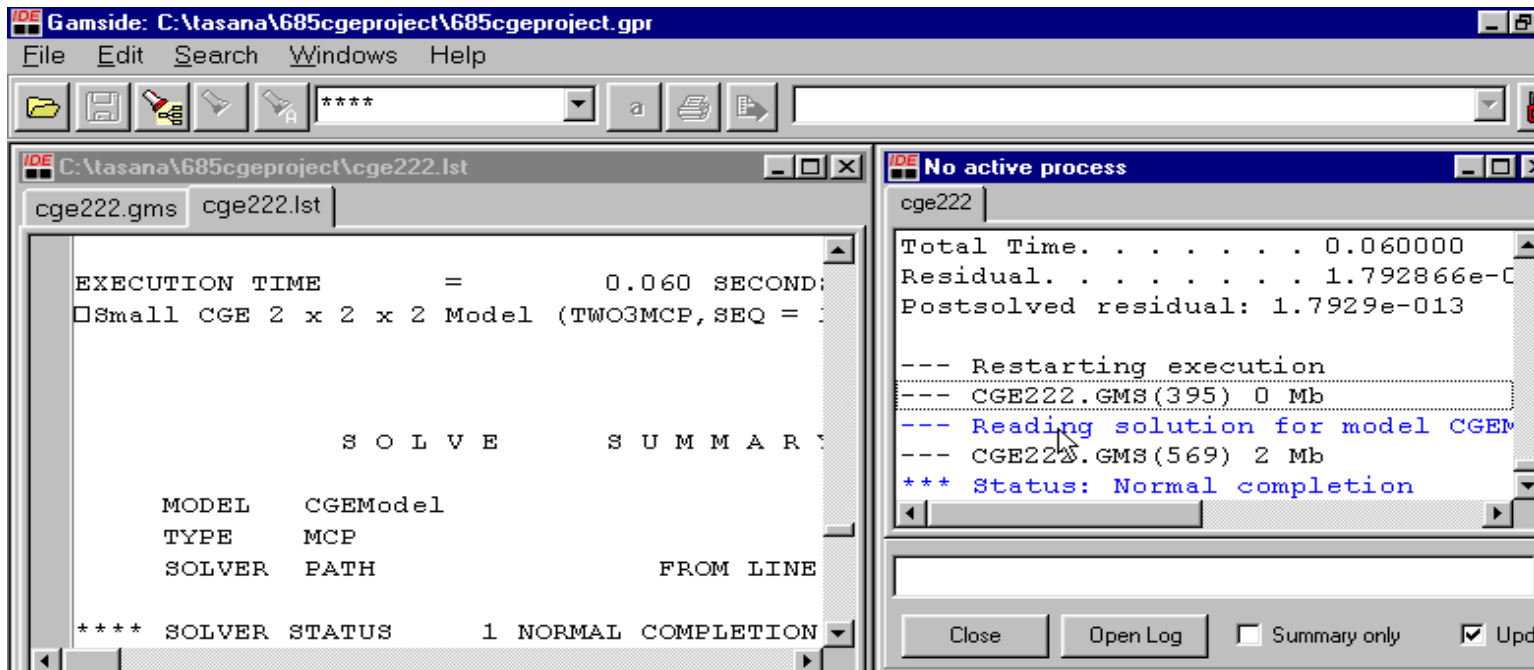
GAMS IDE - Run GAMS

6. Run GAMSIDE

: clicking the run button or pressing F9



As GAMS is running, the process window giving a log of steps will appear.



GAMS IDE - GAMS log

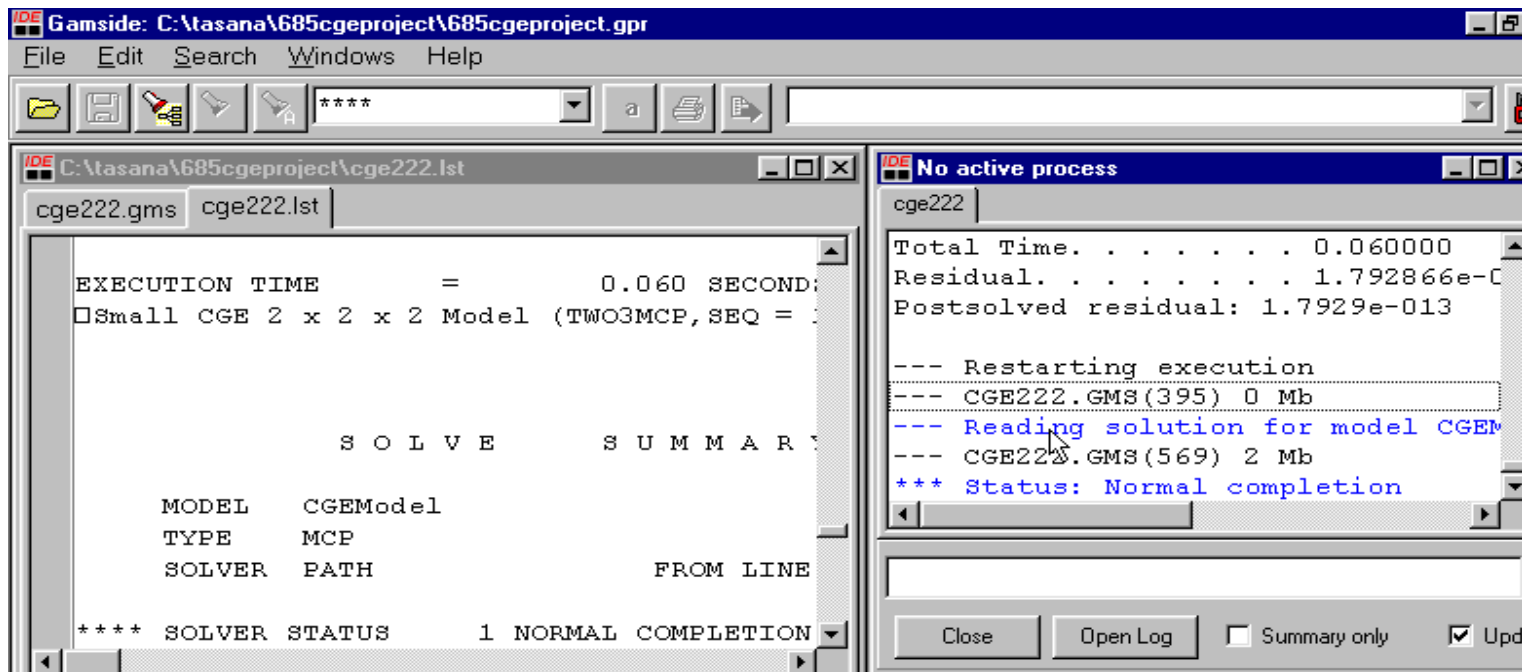
6. Run GAMSIDE (con't)

```
--- Starting compilation                => check if your file is ok
--- SMALLMCP.GMS (26) 1 Mb             => (26) indicate line it is on
--- Starting execution                 => execute your file
--- SMALLMCP.GMS (20) 2 Mb
--- Generating model EQUIL            => set up the problem
--- SMALLMCP.GMS (22) 2 Mb            => size of the problem
---      3 rows, 3 columns, and 6 non-zeroes.
--- SMALLMCP.GMS (22) 2 Mb
--- Executing PATH                    => start solver and gives a
                                       name for which solver is
                                       used
--- Restarting execution              => GAMS restarts
--- SMALLMCP.GMS (22) 0 Mb
--- Reading solution for model EQUIL
--- SMALLMCP.GMS (25) 2 Mb
*** Status: Normal completion        => GAMS stops without errors
```

GAMS IDE - Navigation with IDE

6. Run GAMSIDE (con't)

- : double click on lines in the process window to access output
- : positioning of your access is determined by the color of the line
 - blue lines => open *.LST file and jump to line in *.LST file
 - black lines => open *.LST file and jump to a location of previous blue line
 - red lines => jump to *.gms file (your program) where errors occur



The screenshot displays the GAMS IDE interface. The main window shows the execution output for a GAMS model. The output includes the following text:

```
EXECUTION TIME      =      0.060 SECONDS
□Small CGE 2 x 2 x 2 Model (TWO3MCP, SEQ = ...

          S O L V E          S U M M A R Y

MODEL      CGEModel
TYPE      MCP
SOLVER     PATH          FROM LINE

**** SOLVER STATUS      1 NORMAL COMPLETION
```

The process window, titled "No active process", shows the execution details for the model:

```
cg222
Total Time. . . . . 0.060000
Residual. . . . . 1.792866e-0
Postsolved residual: 1.7929e-013

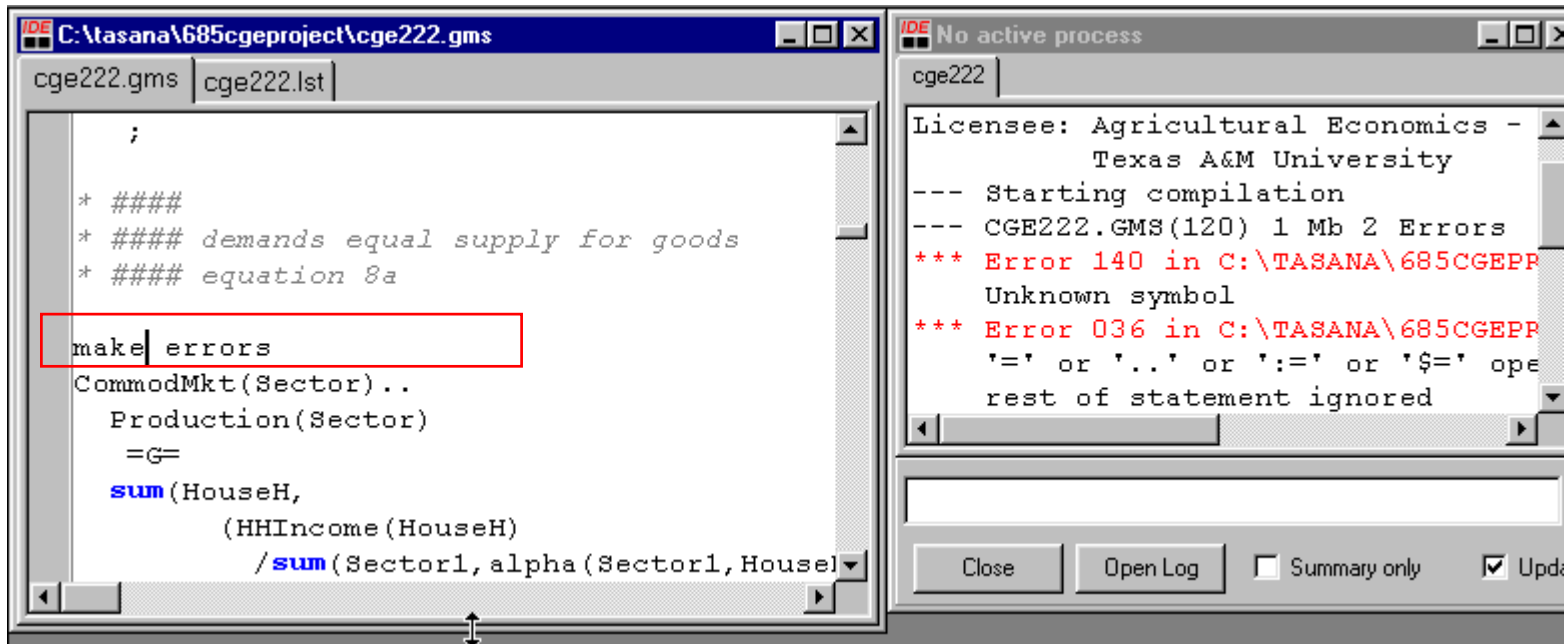
--- Restarting execution
--- CGE222.GMS (395) 0 Mb
--- Reading solution for model CGEM
--- CGE222.GMS (569) 2 Mb
*** Status: Normal completion
```

The process window also features buttons for "Close", "Open Log", and checkboxes for "Summary only" and "Update".

GAMS IDE - Error navigation

6. Run GAMSIDE (con't)

- red lines => jump to *.gms file (your program) where errors were made



The screenshot displays the GAMS IDE interface. The left pane shows the source code for 'cge222.gms'. A red box highlights the line 'make errors'. The right pane shows the compilation log for 'cge222', which includes the following text:

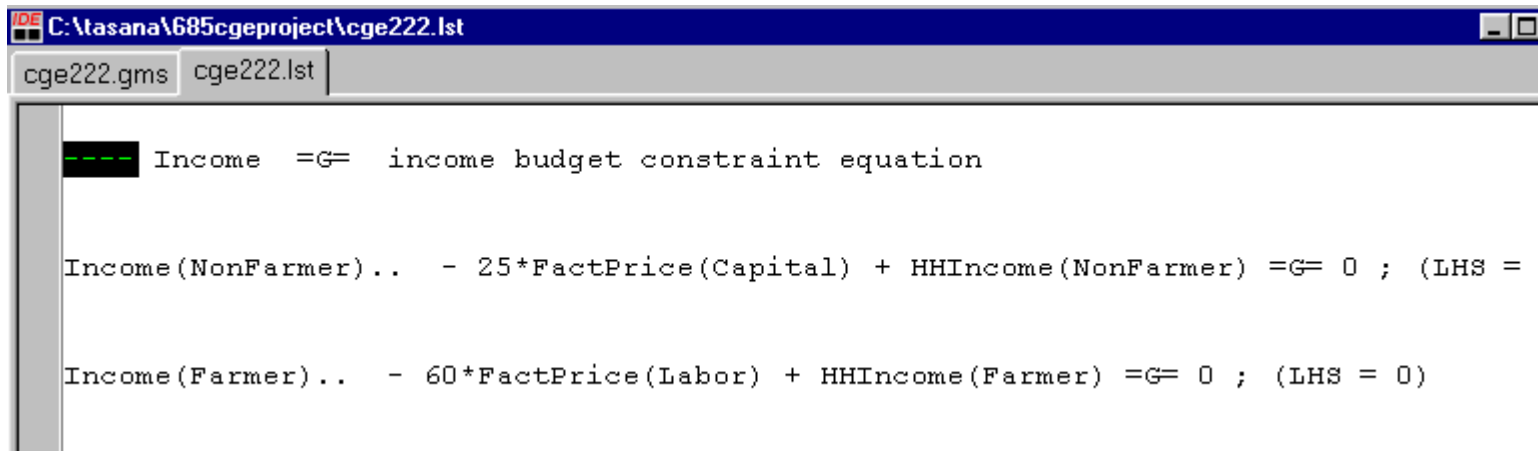
```
Licensee: Agricultural Economics -  
        Texas A&M University  
--- Starting compilation  
--- CGE222.GMS(120) 1 Mb 2 Errors  
*** Error 140 in C:\TASANA\685CGEPP  
Unknown symbol  
*** Error 036 in C:\TASANA\685CGEPP  
'=' or '..' or ':=' or '$=' ope  
rest of statement ignored
```

At the bottom of the right pane, there are buttons for 'Close', 'Open Log', and checkboxes for 'Summary only' and 'Update'.

GAMS IDE - Equation list

7. Navigate around outputs

: look for first ---- to find equation listing in *.LST file

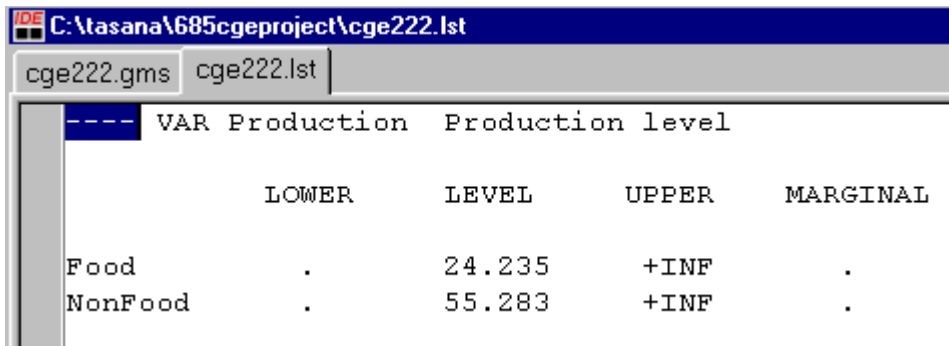


```
C:\tasana\685cgeproject\cge222.lst
cge222.gms  cge222.lst

---- Income  =G=  income budget constraint equation

Income(NonFarmer)..  - 25*FactPrice(Capital) + HHIncome(NonFarmer) =G= 0 ; (LHS =
Income(Farmer)..  - 60*FactPrice(Labor) + HHIncome(Farmer) =G= 0 ; (LHS = 0)
```

: look for the word 'solution' or ---- to find solution



```
C:\tasana\685cgeproject\cge222.lst
cge222.gms  cge222.lst




---- VAR Production  Production level

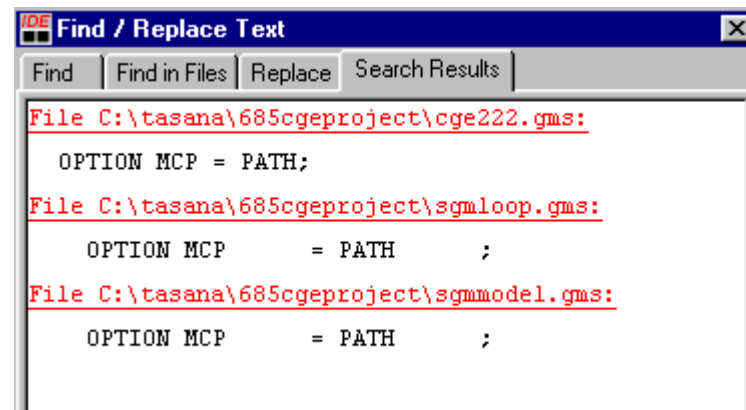
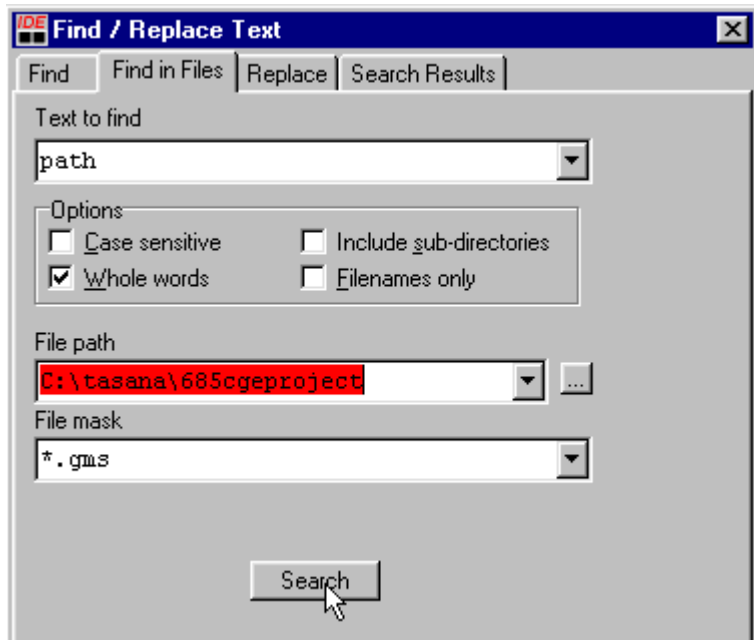
          LOWER      LEVEL      UPPER      MARGINAL
Food          .      24.235      +INF          .
NonFood       .      55.283      +INF          .
```

Useful Tools – Find text

Useful Tools



-  finds the first occurrence in the **current file**
-  finds the next occurrence in the **current file**
-  finds all occurrences in the directory where the project is located



Click on **a red line** to open the file and on **a black line** to open the file and indexes to the particular line

Useful Tools (con't) – Parentheses matching

(a) parentheses match up

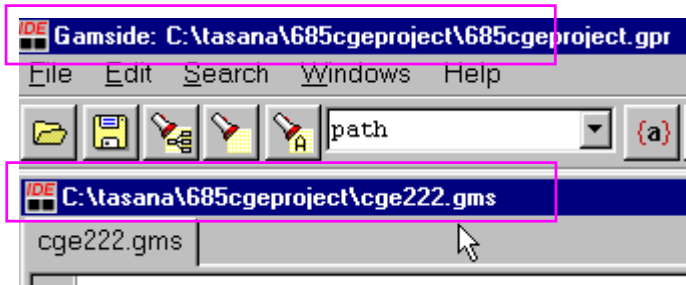
```
CommodMkt(Sector)..
  Production(Sector)
  =
  sum(HouseH,
    (HHIncome(HouseH)
      /sum(Sector1, alpha(Sector1, HouseH)
        *ComPrice(Sector1)**(1-SigmaC(HouseH)))
      )*Alpha(Sector, HouseH) * (1 /ComPrice(Sector))**sigmaC(HouseH)
    )
  )
  )|
```

 `-s =.\t\al` Command line saving parameters once defined in \t\al

 `-r =.\t\al` Command line calling/retrieving saved parameters from \t\al

Caution: Make sure that you are working on files located in the same

directory location as the project is located.



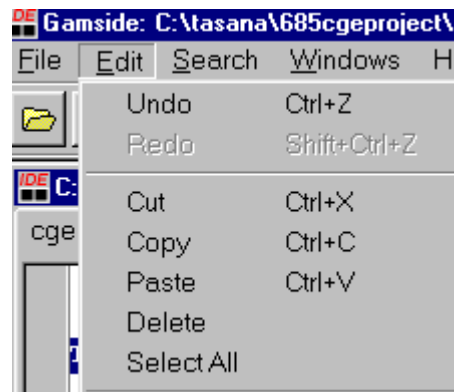
Useful Tools (con't) – Column block

Useful Tools (con't)

ALT+SHIFT moving column blocks of text

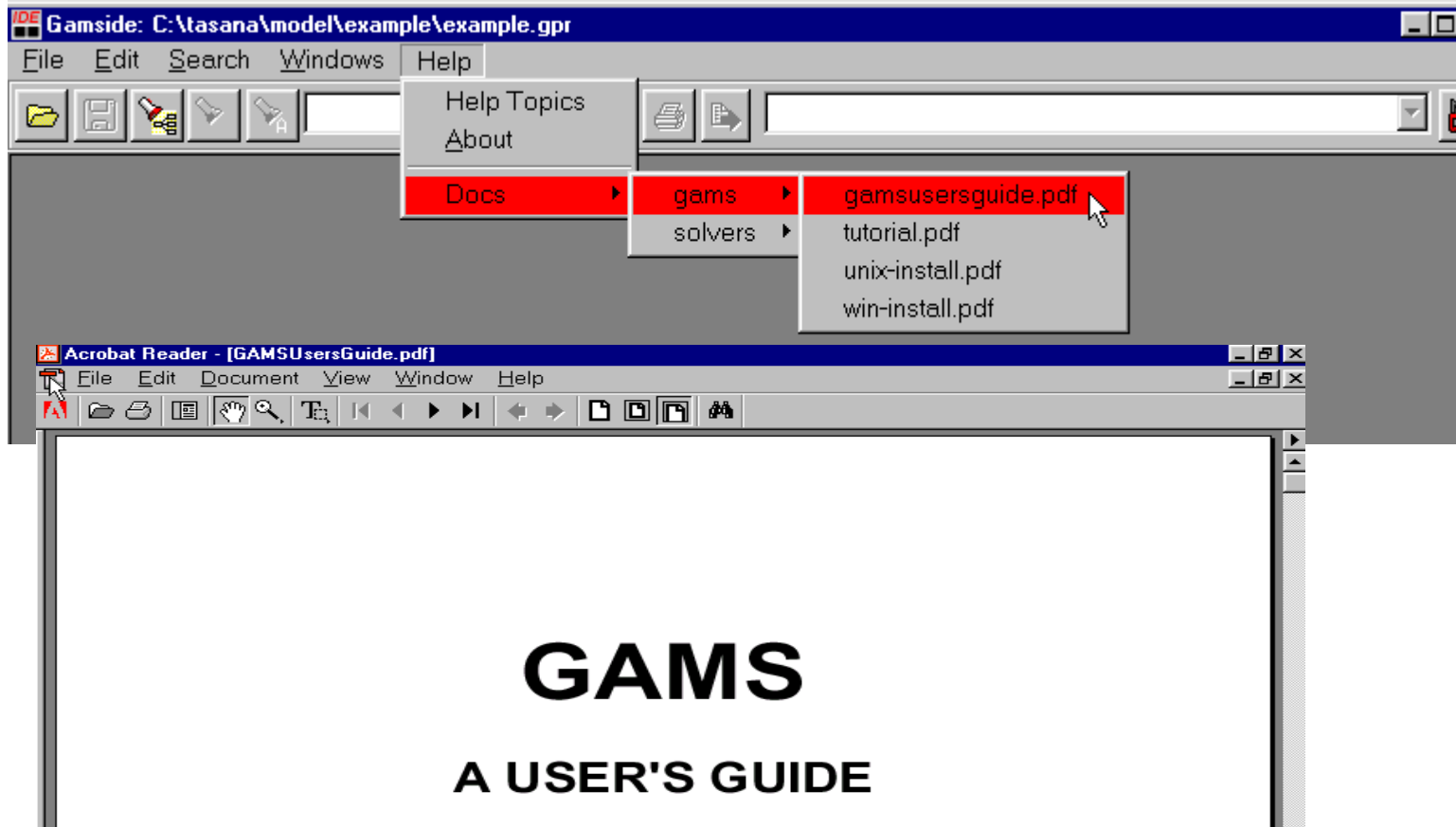
```
TABLE Delta(Factor, Sector)      distribution parameters attached to CES production f
                                     |
                                     |
Labor                               Food   NonFood
Capital                             0.6   0.7
                                     0.4   0.3 ;
```

The copy, cut, and paste can be done with the Edit menus as in normal windows.

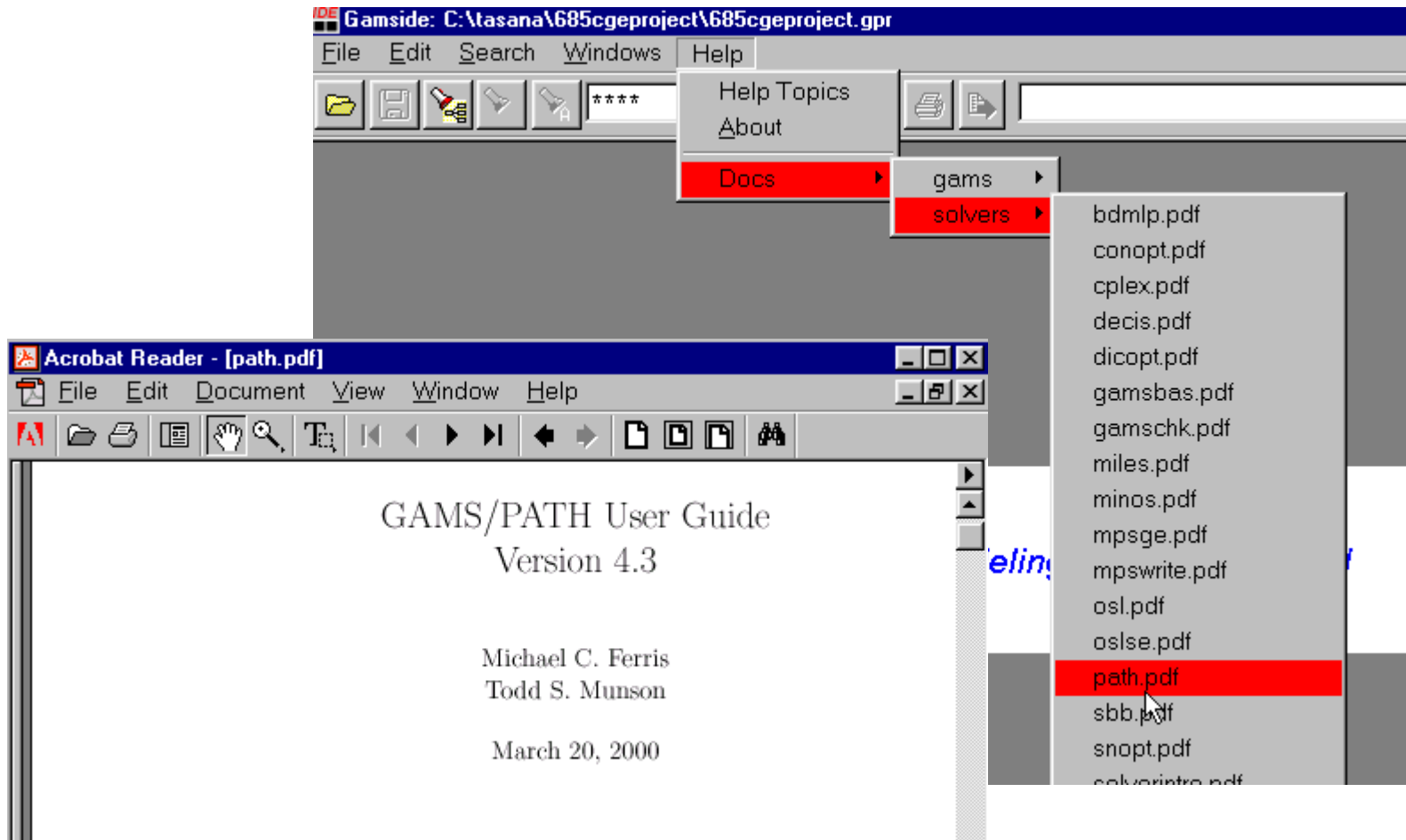


GAMS Documentation – GAMS instruction

- **GAMS** documentation is accessible through the **help** menu under the choice GAMS



GAMS Documentation – Path



Wrap Up

- What is GAMS?
- GAMS IDE
- Useful Tools for GAMS IDE

Next:

- **Casting CGE Modeling via GAMS**
 - : **Set definitions**
 - : **Data entry**
 - : **Variables & Equations specification**
 - : **Identifying complementarity relationship**
 - : **Normalizing prices**
 - : **Solution reports**
 - : **Comparative analysis**

References

McCarl, B. A. Basic GAMS class.
(<http://agecon.tamu.edu/faculty/mccarl/mccarl.htm>).