

Introduction to GAMS Modeling Language

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- Supplementary GAMS tutorial for the CAPRI training session 2023
- Lectures
- Hands-on exercises
- Discussions
- "Homework" try to code the models studied during the tutorials from scratch without any help

Structure of the Tutorial (part I)

Wednesday 6th September

- 1. GAMS modeling language. General introduction; Introduction to GAMS IDE (09:00 - 09:45)
- 2. MyFarm LP model; Main elements of a GAMS model: variables, parameters, equations (10:00 - 10:45)
- **3.** Coding MyFarm LP model in GAMS; Solver output (11:00 11:45)
- **4.** Solver output; Improving efficiency. Sets, Subsets, Alias, Sum (12:15 13:00)

Thursday 7th September

- 1. Introducing Sets and the Sum operator in MyFarm LP; Further useful Gams statements. Prod, Table, Variable-Attributes, Loop (09:00 09:45)
- **2.** Data exchange with Excel (10:00 10:45)

Objectives

- Upon completion of this tutorial, the participants will be able to:
 - Use the GAMSIDE text editor to modify or code economic simulation models in GAMS
 - Understand the logic behind the GAMS modeling language
 - Differentiate between the main elements of a GAMS model
 - Code simple economic models in GAMS
 - Debug these models
 - Analyze the result files generated by GAMS
 - Exchange data between GAMS and Microsoft Excel



• GAMS Documentation (2021). GAMS Development Corporation

What is GAMS?

- General Algebraic Modeling System (GAMS) is a high-level modeling system for mathematical programming and optimization.
- GAMS is "a tool for the development, solution, and management of large scale optimization problems"
- Their main distinguishing features are :
 - the use of relational algebra
 - and the ability to provide partial derivatives on multidimensional, very large and sparse structures
- GAMS enables the user to solve/optimize linear as well as non-linear equation systems
 - Optimization problems (maximization/minimization)
 - Fully determined equation systems
 - Combinations
- GAMS consists of a modeling language (along the lines of standard algebra) and solvers to solve or optimize equation systems.

Key Principles of GAMS

- The problem representation is independent of the solution method.
- The data representation follows the relational data model.
- The problem and data representations are independent of computing platforms.
- The problem and data representations are independent of user interfaces.
- Optimization methods will fail, and systems have to be designed to be fail-safe.

GAMS IDE vs. GAMS Studio

• GAMS IDE

- Written in Delphi
- In use for + 20 years
- Restricted to Windows
- GAMS Studio
 - Written in C++
 - Since 2019
 - Setup similar to IDE
 - Platform-independent





GAMS IDE (Integrated Development Environment) Introduction



GAMS IDE

- A general text editor with the ability to launch and monitor the compilation/execution of GAMS models
- Progress of a compilation/execution can be monitored in the process window
- The IDE also facilitates the selection of default solvers and manages GAMS parameters on a file by file basis

GAMS IDE

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Modeling for the Real World

Organization of the Files



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- Solvers
 - Matrix of available solvers and model types

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- Solvers
 - Matrix of available solvers and model types

Available solvers

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- Available selection
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Running a Model in GAMS IDE

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GAMS Studio

Introduction



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Exercise 1. Linear programming model

LP Model MyFarm



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A linear Programming (LP) Problem: "Myfarm" Example

	Wheat	Barley	Rapeseed	Sugarbeet
Gross margin (€/ha)	253	443	284	516
Labor requirment (hours/ha)	25	36	27	87

- Farms size: 200 ha
- Labor availability: 10000 hours
- X_i: area of land devoted to each crop
- X_i ≥ 0
- Maximize profit

The Mathematical Model

 $Max! Z = 253 * X_{wheat} + 443 * X_{barley} + 284 * X_{rapeseed} + 516 * X_{sugarbeet}$

- Subject to:
- X_{wheat} ; X_{barley} ; X_{rapeseed} ; $X_{\text{sugarbeet}} \ge 0$ (non-negativity)
- $X_{\text{wheat}} + X_{\text{barley}} + X_{\text{rapeseed}} + X_{\text{sugarbeet}} \le 200$ (land)
- $25 * X_{\text{wheat}} + 36 * X_{\text{barley}} + 27 * X_{\text{rapeseed}} + 87 * X_{\text{sugarbeet}} \le 10000$ (labor)
- Where:
- \checkmark X_{wheat}: land area devoted to wheat production
- \checkmark X_{barley}: land area devoted to barley production
- \checkmark X_{rapeseed}: land area devoted to rapeseed production
- \checkmark X_{sugarbeet}: land area devoted to sugar beet production

MyFarm in Excel

Hands-on exercise

 Open the Exercise 01-MyFarm in Excel.xlsx file and solve the LP problem

Questions

- The area devoted to wheat is ____ha. Why?
- Are the land and labour resources fully exploited?
- The max. total gross margin is _____€

The Structure of GAMS Models

Main Elements of a GAMS Model

- 3 essential parts to formulate a GAMS model:
 - Variables
 - Parameters
 - Equations
- To use these in GAMS, 2 steps are required:
 - 1. Declaration: give it a name <u>and</u> tell GAMS what it is, i.e., parameter, variable, equation, ...
 - 2. Assignment or definition (a specific value, type, or function)
- Of course, many more statements are available

GAMS Statement: Variables

- Entities whose values are generally unknown until after a model has been solved
- A GAMS variable, like all other identifiers, must be declared before it may be referenced.
- The syntax

Variables v_obje;

Positive variables v actLevlWHEAT, v actLevlBARLEY, v actLevlRAPESEED, v actLevlSUGARBEET;

 Variable(s) 	Keyword for variable definition
 Positive/Binary 	Keyword can be preceded by modifier:
• Positive	The variable can only contain nonnegative values
• Binary	Only 0 and 1 allowed
• v_actLevlWHEAT,	List of variable identifiers
• • •	Semicolon ends each GAMS statement

GAMS Statement: Variables. Syntax

[var_type] variable[s] var_name [text]

Keyword	Description	Default Lower Bound	Default Upper Bound
free (default)	No bounds on variable. Both bounds may be changed from the default values by the user.	-inf	+inf
positive OF nonnegative	No negative values are allowed for variable. The user may change both bounds from the default value.		+inf
negative	No positive values are allowed for variables. The user may change both bounds from the default value.	-inf	0
binary	Discrete variable that can only take values of 0 or 1. For details see section Types of Discrete Variables. In relaxed Model types the integrality requirement is relaxed.	0	1
integer	Discrete variable that can only take integer values between the bounds. The user may change both bounds from the default value. The default upper bound inside GAMS is +inf but when the variable is passed on to the solver, the option or command line parameter IntVarUp decides what upper bound (by default 100) is passed on to the solver in case GAMS has upper bound +inf. In relaxed Model types the integrality requirement is relaxed.	0	+inf
3031	A set of variables, such that at most one variable within a group may have a non-zero value. For details see section Types of Discrete Variables.	0	+inf
3032	A set of variables, such that at most two variables within a group may have non-zero values and the two non-zero values are adjacent. For details see section Types of Discrete Variables.	0	+inf
semicont	Semi-continuous, must be zero or above a given minimum level. For details see section Types of Discrete Variables.	1	+inf
semiint	Semi-integer, must be zero or above a given minimum level and integer. For details see section Types of Discrete Variables. The default upper bound inside GAMS is +inf but when the variable is passed on to the solver, the option or command line parameter IntVarUp decides what upper bound (by default 100) is passed on to the solver in case GAMS has upper bound +inf. In relaxed Model types the integrality requirement is relaxed.	1	+inf

GAMS Statement: Variables

- Good modeling practice:
 - Use expressions which are short (one word) but are still telling
 - Not VAR1, A, B
 - Add explanatory text to further clarify the meaning:

```
Variables

v obje objective function value

;

Positive variables

v_actLevlWHEAT land area wheat

v_actLevlBARLEY land area barley

v_actLevlRAPESEED land area rapeseed

v_actLevlSUGARBEET land area sugar beet

;
```
- Are constants and contain exogenously given values
- Are not modified during the solution process

Parameters

p_uvag_wheat	Gross	margin	of	wheat	/253/,
p_uvag_barley	Gross	margin	of	corn	/443/,
p_uvag_rapeseed	Gross	margin	of	rapeseed	/284/,
p_uvag_sugarbeet	Gross	margin	of	sugar beet	/516/,
;					

• Where

•	Parameters	Keyword for parameter definition
•	p_uvag_wheat	Identifier of the parameter
•	/253/	Initial assignment of a value (otherwise: 0)
•	<i>r</i>	To define more parameters in one statement, separate them by commas or breaks
٠	;	Every GAMS statement is concluded by a semicolon

Good modeling practice: Separate declaration and assignment

```
Parameters
p_uvag_wheat Gross margin of wheat
p_uvag_barley Gross margin of barley
;
p_uvag_wheat = 253;
p_uvag_barley = 443;
```

• Assignment may contain arithmetic operations, e.g.

Operation	Symbol	Order of Precedence
Exponentiation	**	1
Multiplication	*	2
Division	/	2
Addition	+	3
Subtraction	-	3

• Values of parameters can be "overwritten":

```
Parameters
p_uvag_wheat Gross margin of wheat
gm_barley Gross margin of barley
;
p_uvag_wheat = 253;
p_uvag_barley = 443;
p_uvag_wheat = 378;
```

• To check the value of a parameter or variable use the display statement:

```
DISPLAY p_uvag_wheat;
or
Display p_uvag_wheat;
or
display p_uvag_wheat;
or
displAy p_uvag_wheat;
```

• In GAMS, each equation consists of 2 separate statements:

- Declaration (declare the equations existence)
- Definition (the equation itself, its algebraic form)
- Declaration:

Equations e_land, e_labour, obje;

- Where
 - Equations
 - e_land,... obje
 - ;

Keyword for equation declaration List of equations to be declared End GAMS statement

• Definition

- Equation name followed by two dots (..)
- Then the algebraic form of the equation
- In equations, the relational operators $(= \le \ge)$ must be written as:
 - =E= Equality: right-hand side must equal left-hand side
 - =G= Greater than: left-hand side must be greater than or equal to righthand side
 - =L= Less than: left-hand side must be less than or equal to right-hand side

• Definition

• Equation definitions for the MyFarm-exercise:

obje .. v_obje =E= p_uvag_wheat * v_actLevlWHEAT + p_uvag_barley *
v_actLevlBARLEY + p_uvag_rapeseed * v_actLevlRAPESEED + p_uvag_sugarbeet *
v actLevlSUGARBEET;

e_land .. v_actLevlWHEAT + v_actLevlBARLEY + v_actLevlRAPESEED +
v actLevlSUGARBEET =L= 200;

e_labour .. p_lab_wheat * v_actLevlWHEAT + p_lab_barley * v_actLevlBARLEY +
p_lab_rapeseed * v_actLevlRAPESEED + p_lab_sugarbeet * v_actLevlSUGARBEET =L= 10000;

- Definition
 - Note: The general form of these statements is

equationname.. algebra1 relation algebra2;

- Where
 - equationname
 - . .
 - algebra1, algebra2
- The identifier of the equation as declared Separator between name and equation Some algebraic expressions containing parameters and at least one endogenous variable One of the following =E= or =L= or =G=

- relation
- ;

End of the statement

GAMS Statement: Model

 Once all the model structural elements have been defined, the model has to be defined by a Model statement to identify the equations that belong to the model.

```
Model myfarm /e_land, e_labour, obje/;
Or
Model myfarm /all/;
```

- Where
 - Model Keyword for model definition
 - Myfarm Identifier for this model
 - /e_land, .../ List of equations that belong to this model
 Ends the statement
 - Ends the statement
- The keyword all includes all previously defined equations in the model.

GAMS Statement: Solve

• The Solve statement causes GAMS to use a solver to optimize/solve the model

Solve myfarm using lp maximizing v_obje;

• Where

•

•

•

v obje

;

- solve Keyword for the solve statement
- myfarm
 Name of the model to be solved
 - using lp Declares type of solver to be used (lp = linear programming)
 - maximizing Declares the direction of the optimization
 (alternative: minimizing)
 - Target variable (has to be defined before and has to occur in the model, must not be restricted)
 - Ends the statement

Good Modelling Practices

- Enhance the readability of the model (to others/ to you after some time of absence) by:
 - Ordering: e.g. first define all parameters, variables,...then assign them
 - Giving telling names to model-entries ("p_uvag_wheat" instead of "par_1")
 - Defining all entries using explanatory text
 - Specify units of all entries (e.g. ha, 1000 USD,...)
 - Use comments wherever useful:

```
* starts a comment-line
$ontext
starts a comment which can stretch over several lines and needs to
be ended by
$offtext
```

Exercise 2. Linear programming model in GAMS

Coding the MyFarm Model



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MyFarm Model

The problem

Farmer wants to maximize his profit given 100 ha of land and 500 hours of labor. He/she has the option of cultivating wheat, barley rapeseed and/or sugarbeet. How much of each crop should be plated in order to maximize the profit.

	Wheat	Barley	Rapeseed	Sugarbeet
Gross margin (€/ha)	253	443	284	516
Labor requirment (hours/ha)	25	36	27	87

Questions

- The value of an additional unit of land is _____€
- If we include 1 ha of wheat in the cropping mix, the tot. gross margin will increase/decrease by _____€

Solver Output: the Listing File

The Listing File ".lst"

- The output file generated from a GAMS run is called listing file
- The listing file contains (in standard settings)
 - Echo print
 - Error messages
 - Equation listing
 - Column listing (variables)
 - Model statistics
 - Solution report
 - SolEQU, SolVAR:
 - Solution values for equations and variables

The Listing File "Echo print"

- Is always the first part of the output file
- It is a listing of the input with added line numbers

23	Variables		
24	w obje objective function		
25	<pre>v_obje objective function</pre>	n value	
28	,		
26			
27	Positive variables		
28	v_actLev1WHEAT land	d area wheat	
29	v_actLev1BARLEY land	d area barley	
30	v_actLev1RAPESEED land	d area rapeseed	
31	v_actLev1SUGARBEET land	d area sugarbeet	
32	;		
33			
34	Parameters		
35	p_uvag_wheat	Gross margin of wheat	/253/ ,
36	p_uvag_barley	Gross margin of barley	/443/ ,
37	p uvag rapeseed	Gross margin of rapeseed	/284/ ,
38	p uvag sugarbeet	Gross margin of sugarbeet	/516/ ,
39			
40	p lab wheat	Required labor hours of wheat	/25/ .
41	p lab barley	Required labor hours of barley	/36/
42	p lab rapeseed	Required labor hours of rapeseed	/27/
43	n lab sugarbeet	Required labor hours of sugarbeet	/87/
44		Acquired labor month of Sugarbeet	,
45	,		
46			
47	Emistions		
40	*Declaration		
40	Declaration		
50	- 1		
50	e_iand iand constraint		
51	e_iabour iabour constraint		
52	obje objective function	n	
53	;		
54			
55	*Defintion		
56	obje v_obje =E= p_u	vag_wheat * v_actLev1WHEAT + p_uvag_b	arley * v
	_actLev1BARLEY + p_uvag_rape	<pre>seed * v_actLev1RAPESEED + p_uvag_sug</pre>	arbeet *
	v_actLev1SUGARBEET;		
57			
58	e_land v_actLev1WHEAT	+ v_actLev1BARLEY + v_actLev1RAPESEE	D + v_act
	Lev1SUGARBEET =L= 200;		
59			
60	e_labour p_lab_wheat * v	v_actLevlWHEAT + p_lab_barley * v_act	LeviBARLE
	Y + p_lab_rapeseed * v_actLe	vlRAPESEED + p_lab_sugarbeet * v_actI	evlSUGARB
	EET =L= 10000;		
61			
62			
63			
64	Model myfarm /all/;		

66 Solve myfarm using lp maximizing v obje;

The Listing File "Error messages"

- All errors are marked by 4 stars (****)
 - Search for **** to find errors in the listing file
- Two types of error messages:
 - 1. Compilation errors (syntax/consistency mistakes)
 - \$errornumber is placed below the exact position in the line where the error occurred
 - errornumber is referenced by an error listing that describes this error
 - 2. Execution errors (illegal arithmetic operations)
 - Errors after compilation finished, i.e., during model generation and solving

The Listing File "Error messages" Examples

Compilation error

 A dollar symbol and error number are printed below the offending symbol on a separate line that begins with four asterisks

```
55 *Definition
56 obje .. v_obje =E= p_uvag_whea * v_actLevlWHEAT + p_uvag_barley * v_
**** $140
actLevlBARLEY + p_uvag_rapeseed * v_actLevlRAPESEED + p_uvag_sugarbeet * v
_actLevlSUGARBEET;
**** 140 Unknown symbol
```

• Execution error

Occurs after compilation has finished

```
58 e_land .. v_actLevlWHEAT + v_actLevlBARLEY + v_actLevlRAPESEED + v_act
LevlSUGARBEET =L= 200/0;
```

**** Exec Error at line 58: division by zero (0)

The Listing File "Equation listing"

- Is the first part of the output generated by a solve statement
- By default, the first three equations in every block are listed
 - This can be modified with the option limrow

```
Equation Listing SOLVE myfarm Using LP From line 66
---- e_land =L= land constraint
e_land.. v_actLevlWHEAT + v_actLevlBARLEY + v_actLevlRAPESEED
  + v_actLevlSUGARBEET =L= 200 ; (LHS = 0)
---- e_labour =L= labour constraint
e_labour.. 25*v_actLevlWHEAT + 36*v_actLevlBARLEY + 27*v_actLevlRAPESEED
  + 87*v_actLevlSUGARBEET =L= 10000 ; (LHS = 0)
---- obje =E= objective function
obje.. v_obje - 253*v_actLevlWHEAT - 443*v_actLevlBARLEY
  - 284*v_actLevlRAPESEED - 516*v_actLevlSUGARBEET =E= 0 ; (LHS = 0)
```

• For equalities: LHS should be equal to RHS, typically 0.

The Listing File "Column listing"

• The column listing or variable listing is the next part of the output



The Listing File "Model statistics"

Model Statistics	SOLVE	myfarm Us:	ing LP Fr	om line 59		
MODEL STATISTICS						
BLOCKS OF EQUATIONS BLOCKS OF VARIABLES NON ZERO ELEMENTS		3 5 13	SINGLE E SINGLE V	QUATIONS ARIABLES	3 5	
GENERATION TIME	=	0.015	SECONDS	3 MB	39.2.1 98a2c774	WEX-WEI

The Listing File "Solution report"

 It is marked with the title Solution Report and includes the solve summary, the solver report, the solution listing, and the report summary

```
General Algebraic Modeling System
Solution Report SOLVE myfarm Using LP From line 59
            SOLVE SUMMARY
          myfarm
   MODEL
                        OBJECTIVE Z
    TYPE
          L.P
                           DIRECTION MAXIMIZE
    SOLVER CPLEX
                           FROM LINE 59
**** SOLVER STATUS
                   1 Normal Completion
**** MODEL STATUS
                   1 Optimal
**** OBJECTIVE VALUE
                          92607.8431
RESOURCE USAGE, LIMIT
                          0.016 10000000000.000
ITERATION COUNT, LIMIT
                     2
                              2147483647
```

The Listing File "The Solution Listing"

- The solution listing is a row-by-row then column-bycolumn listing of the solutions returned to GAMS by the solver program
- Each individual equation (SolEQU) and variable (SolVAR) is listed with four pieces of information
 - May be suppressed by

option solprint = off ;

Shadow price SolEQU: LOWER LEVEL UPPER MARGINAL ---- EQU e land -INF 391.471 200.000 200.000 ---- EQU e labour -INF 10000.000 10000.000 1.431 ---- EQU obje 1.000 . .

The Listing File "The Solution Listing"

• SolVAR:

				Reduced cos	st
	LOWER	LEVEL	UPPER	MARGINAL	
VAR v_obje	-INF	92607.843	+INF		
VAR v_actLevl~			+INF	-174.255	
VAR v_actLevl~		145.098	+INF		
VAR v_actLevl~			+INF	-146.118	
VAR v_actLevl~		54.902	+INF		

The Listing File "Report Summary"

**** REPORT SUMMARY :

- NONOPT INFEASIBLE
- 0 UNBOUNDED

0

0

Improving the Efficiency of Coding in GAMS

Introducing Sets in the GAMS model

The Mathematical Model

 $Max! Z = 253 * X_{wheat} + 443 * X_{barley} + 284 * X_{rapeseed} + 516 * X_{sugarbeet}$

- Subject to:
- X_{wheat} ; X_{barley} ; X_{rapeseed} ; $X_{\text{sugarbeet}} \ge 0$ (non-negativity)
- $X_{\text{wheat}} + X_{\text{barley}} + X_{\text{rapeseed}} + X_{\text{sugarbeet}} \le 200$ (land)
- $25 * X_{\text{wheat}} + 36 * X_{\text{barley}} + 27 * X_{\text{rapeseed}} + 87 * X_{\text{sugarbeet}} \leq 10000$ (labor)
- Where:
- \checkmark X_{wheat}: land area devoted to wheat production
- \checkmark X_{barley}: land area devoted to barley production
- \checkmark X_{rapeseed}: land area devoted to rapeseed production
- \checkmark X_{sugarbeet}: land area devoted to sugar beet production

An Alternative Formulation

Max
$$\sum_{j} c_{j} X_{j}$$

s.t. $\sum_{j} a_{ij} X_{j} \le b_{i}$
 $X_{j} \ge 0$

Where

- j = {wheat, barley, rapeseed, sugarbeet}
- i = {land, labor}
- $X_j = \{X_{wheat}, X_{barley}, X_{rapeseed}, X_{sugarbeet}\}$
- $C_j = \{253, 443, 284, 516\}$
- $a_{ij} = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 25 & 36 & 27 & 87 \end{pmatrix}$
- $b_i = \{200, 10000\}$

GAMS Statement: Sets

• If we have several parameters or variables of the same type, we can use sets as indices for these parameters or variables

SET COLS /wheat, barley, rapeseed, sugarbeet/;

• Where

Set(s)	Keyword for set definition
COLS	Identifier of the set
/wheat,/	List of set elements

Use of a set in a parameter definition:

ag(crops)	/wheat	253,
	barley	443,
	rapeseed	284,
	sugarbeet	516/;
	ag(crops)	ag(crops) /wheat barley rapeseed sugarbeet

GAMS Statement: Sets

 Assigning all the parameters of the set, overwriting it or referring to it:

p_uvag(crops) = 90;

• Referring to a single element of a set or overwriting it :

p_uvag("wheat") = 90;

GAMS Statement: Sets

• The format for the set declaration and element definition statement is:

SET	setname		optional	explanatory	text
	/first set-element	name	optional	explanatory	text
	second set-element	name	optional	explanatory	text
	 /;				

- The word **set** or **sets** can be used.
- Multiple sets can be stacked with the set or sets keyword only used once.
- When multiple sets are defined in one set statement a ";" is entered after all set definitions only:

```
SETs j /x1,x2,x3/
i /r1
r2/;
```

• Set elements are separated by commas or by an end-of-line.

Sequences as Set Elements

- The asterisk '*' plays a special role in set definitions.
 - Used to define sequence of elements for a set

```
Set t "time" / 1991 * 2000 /;
```

• This means:

Set t "time" /1991,1992,1993,1994,1995,1996,1997,1998,1999,2000/;

• If the only characters that differ are digits then a label is constructed for every integer in the sequence

```
Set g1 /albc*a20bc/;
• But
Set crops /wheat * cott/;
=> ****Error
```

GAMS Statement: Alias

• Sometimes it is necessary to have more than one name for the same set

SET COLS /wheat, barley, rapeseed, sugarbeet/;

Alias (COLS, CACT);

- The newly introduced set name may be used as an alternative name for the original set; the associated set will always contain the same elements as the original set.
- The order of the set names in the alias statement does not matter.



• It is often necessary to define sets whose members must all be members of some larger set:

SETs COLS /wheat, barley, rapeseed, sugarbeet/

export(COLS) /wheat, barley/ ;

• Where

SETs	Keyword for set definition
export	A subset of the larger set
(COLS)	The original set also called superset
/wheat,barley/	Set elements of the subset

• All elements of the subset must also be elements of the superset.

Introducing Sum in the GAMS model
GAMS Statement: Sum

 Example: to sum all values of X over an index i element of set i={1,2,3,4,5}, in formula notation:

$$Y = \sum_{i=1}^{\circ} X_i$$

• In GAMS, this can be written as follows:

```
Set I /1,2,3,4,5/ ;
Parameters X(I), Y;
Y = sum (I, X(I));
```

GAMS Statement: Sum

• The general syntax is:

sum(settovary,expression)

- Where
 - settovary the name of the set or sets that will be varied
 expression generally a function of the set in the sum
- When more than one set is to be varied they are enclosed in parentheses:

sum((i,j),x(i,j))

Exercise 3. Introduce Set and Sum to Myfarm Example

- Modify the previous model:
 - ✓ Introduce a set "COLS"
 - ✓ Introduce parameters "p_uvag" and "p_lab"
 - ✓ Let these run over the set "COLS"
 - ✓ Let the variable v_actlevl run over the set "COLS"
 - Modify the equations such that you have a sum statement in each of the equations

Further Useful GAMS Statements

GAMS Statement: Prod

 Products are defined in GAMS using exactly the same format as summations, replacing Sum by Prod

•
$$Y = \prod_i X_i$$

• In GAMS, this can be written as follows:

Y = prod(I, X(I));

GAMS Statement: Table

• Tabular data can be declared and initialized in GAMS using a table statement.



• Where

Table

Keyword for table definition

Variable Attributes

- While a GAMS parameter has one number associated with each unique label combination, a variable has several
 - ✓ .lo Lower bound for the variable
 - ✓ .up Upper bound for the variable
 - \checkmark .fx A fixed value for the variable
 - ✓ .I Activity level for the variable, also the current value or starting point. This attribute is reset to a new value when a model containing the variable is solved.
 - .m The marginal value (or reduced cost) for the variable. This attribute is reset to a new value when a model containing the variable is solved.

Variable Attributes

• For example, in the Myfarm model, fix the area devoted to wheat 60 ha:

```
Positive variable
v_actLevl(crops) land area planted with crop
;
v_actLevl.fx("wheat") = 60
;
```

GAMS Statement: Loop

- The loop statement facilitates executing a group of statements for each member of a set.
- The syntax of the Loop statement is

```
Loop((sets_to_vary),
Statement/statements to execute);
```

Example

```
set Y 'years' /2011*2020/;
parameter pop(y) 'population' /2011 100/
        grate(y) 'growth rate';
        grate(y) = 0.02;
loop(y, pop(y+1) = pop(y) *(1+grate(y)));
display pop;
```

Data Exchange with Microsoft Excel

Data Exchange in GAMS

• GAMS can communicate with Microsoft Excel via GDX (GAMS Data Exchange) files

- A GDX file is a file that stores the values of one or more GAMS symbols such as sets, parameters variables and equations.
- A GDX file does not store a model formulation or executable statements.

From GAMS to Excel

1. Writing the data into a GDX file (during the execution time)

execute_unload "results.gdx" v_actLevl, v_obje

Where

execute_unload	
"results.gdx"	

v_actlevl, v_obje

GAMS statement to create a GDX file containing selected problem data The Name of the GDX file to be created Items written to GDX file

- ✓ Without specifying any identifier, all sets, parameters, variables and equations will be written to the GDX file.
- Implement the code in the Myfarm model and open the GDX file in GAMSIDE.

From GAMS to Excel

2. Converting the GDX file to Excel file



• Where

Execute	GAMS keyword
gdxxrw.exe	Utility to read and write Excel spreadsheet data
results.gdx	GDX input file generated by step 1
o=results.xlsx	Excel output file
var=	Specify the variables you want to export. In case of parameters use <pre>par=</pre>
rng=sheet1!A1′	Excel sheet name and for cell range to be used. If skipped, the data is written in cell A1 and beyond in the first available sheet.

Exercise 4. From GAMS to Excel

- Write the variable levels to Sheet1 of the Excel file called "MyFarm_results.xlsx"
- Write the marginal values of the variables to Sheet2 of the same Excel file.
- Question
 - Why are only the values for barley and sugarbeet exported?

From Excel to GAMS

1. Unload the data from Excel to GDX file

\$call GDXXRW data.xlsx o=data.gdx par=parname rng=sheet1!B3:F5

	Α	В	С	D	E	F
1	MyFarn	n Data				
2						
3			wheat	barley	rapeseed	sugarbeet
4		uvag	253	443	284	516
5		lab	25	36	27	87
6						

• Where

\$call
GDXXRW
data.xlsx
o=data.gdx
par=parname
rng=sheet1!B3:F5

The command to execute a program called GDXXRW The utility to read the .gdx file The excel file located in the same project directory The generated .gdx file Parameter to be loaded to the GDS file Range of the data in Excel

From Excel to GAMS

2. Read in the data from the GDX file

```
Parameter
```

```
Data(*,cols)
$GDXIN data.gdx
$LOAD or $LOADdc data
$GDXIN
gm(cols) = data("uvag",cols);
lab(cols) = data("lab",cols);
```

• Where

\$GDXIN	command used in a sequence either to load specified items from a GDX file or to close the specified GDX file.
\$LOAD	command loads specified items from a GDX file.
\$LOADdc	domain check: element names being loaded are in the associated sets. In contrast, the \$load command simply ignores elements that are not in the domain

Exercise 5. From Excel to GAMS

- Create an Excel file and call it data.xlsx
- Include the required data into data.xlsx
- Instead of defining the parameter values in GAMS, import them from data.xlsx