GAMS Tutorial

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Why use GAMS?

- Allows us to solve generalized models
- No need to write explicit equations
- Programmatic expression of equations helps us in achieving a better understanding of modelling
- Can solve various types of optimization problems
- You'll most likely need to use GAMS in the future
- Why just settle with only the theory, get your hands dirty!
- Programming is cool.

- Recall that, optimization means finding the best alternative with respect to a function over a set constrained by other functions.
- Sets are the foundation upon which the entire model is built.
- Time to stop thinking in terms of x_{12}. It's high time you thought in terms of x_{ij}

if

$$I = \{1, 2, 3, ..., i\}$$

and

$$x_i = 1 \qquad \forall i \in I$$

then, it means

$$x_1 = 1$$
$$x_2 = 1$$
$$...$$
$$x_i = 1$$

if

$$I = \{1, 2, 3, ...i\}$$

and

$$\sum_{i \in I} x_i = 1$$

then, it means

$$x_1 + x_2 + x_3 + ... + x_i = 1$$

Beware that, without an "order" for an index the expression becomes meaningless.

$$\sum_{i \in I} x_{ij} = 1$$

$$x_{1j} + x_{2j} + x_{3j} + ... + x_{ij} = 1$$

In GAMS, sets are declared either by

- set i /1,2,3,4,5/;
  sej j /a,b,c,d,e/;

or

- Sets
  i /1,2,3,4,5/
  j /a,b,c,d,e/;

GAMS is not case sensitive! you can use both SETS and sets to the same effect.
Notice the single ";" when declaring sets in a single command.

- set i /d1,d2,d3,d4,d5/; is the same as set i /d1*d5/;
- You could also import data from excel.

the alias command is vital for the more complex models,

- When you need to define more than more indices for a single set, you'll require alias
- alias(i,j); allows you to create a copy of the set i for multiple purposes
- Allows the modification of variable indices and the subsetting of sum or forall expressions if necessary

Data Entry

- You can define scalars, parameters or tables
- Same syntax rules apply!

scalar M /1000/;

- Defines a scalar M = 1000

parameter k(i) /i1 10, i2 65, i3 23, i4 12, i5 14/;

- Assuming that I ={i1,i2,i3,i4,i5}, the command above defines a one dimensional list corresponding to the set I.
- The number of items inside the list must be equal to the number of elements inside the set I

- Tables can be defined in a similar manner. You should, however, pay attention to how the sets are previously defined.
- Assume I = {Ankara, Istanbul, Izmir} J = {Winter, Summer}

```
table W(i,j)
       Winter Summer
Ankara    5 4
Istanbul    10 3
Izmir    20 21;
```

- The command above defines a two dimensional table (or a matrix). The elements do not need to be perfectly aligned. Defining multi-dimensional tables is also possible!

- As stated earlier, MS Excel could be used as the data source instead of putting in tables by hand on GAMS.
- A call to a plugin is required to facilitate the interface between excel and GAMS, as shown below.

```
Table(i,j)
$call =xls2gms r=sheetName!namedCells i=excelfile.xlsx
o=table1.inc
$include table1.inc
```

- xl2gms is pre-installed in the latest versions of GAMS.
- You can both use named cells on Excel, or cell intervals like A1:C10 to tell GAMS where your data is located.
- There is no need to put semi-colon after defining your parameters via excel. The excel file must be in your project directory.

Defining Variables

- Variables must be properly defined and their nature must be set. (Binary, Nonnegative etc.)

```
Variables
x(i,j) additional comments;
```

- Defines a variable over sets i and j.
- The definition must be succeeded by a statement about the nature of the variable.

```
binary variables x;
nonnegative variables y;
```

- The seperate commands above, defines x as a binary variable and y as a nonnegative variable, respectively.
- The objective function must be defined as a stand-alone variable.

Defining Equations

- Equations with their proper domains must first be defined, akin to variable declarations in many programming languages.
- Equations include both the constraints of the model and the objective functions.

```
Equations
obj "this is the objective function"
constraint1(i,j) comments
constraint2(i) comments
;
```

- The portion of code above shows the declaration of three equations, the first could be used as the objective function while the other two represent constraints in the model.

- The equation declarations constraint1(i,j) and constraint2(i) display vital information.
- constraint1 is defined for all i and j.

$$constraint1 : \forall i \in I, j \in J$$

- constraint2 is defined for all i.

$$constraint2 : \forall i \in I$$

- After equation declarations, mathematical expressions can be defined to the equations.
- The mathematical definitions should be consistent with what has previously been declared for equations or else you're going to get an error.

```
constraint2(i).. sum((j),W(i,j)*x(i,j) =l= M;
```

- The command above is equivalent to the expression below.
- Yes, .. is necessary.

$$\sum_{j \in J} x_{ij} * W_{ij} \leqslant M \qquad \forall i \in I$$

- The definition of the objective function with the exclusively declared equation and variable is necessary.

```
obj.. z =e= sum((i,j), x(i,j));
```

- The command above is equivalent to the expression below:

$$\sum_{i \in I} \sum_{j \in J} x_{ij} = z$$

- Notice that, there is no input indicating as to whether the objective function is being maximized or minimized. This takes place later.

- There are several commands that either are required to run the model or can be used to display important information.
- These should be written after all the previously mentioned definitions are made.

```
Model modelname /all/;
```

- The command above names the model and tells GAMS which elements to include.
- /all/ indicates that everything that has been defined is going to be included in the attempted solution.

option limrow = 100;

- With option it is possible to tweak and customize the output.
- The option limrow above expands the default limit of displaying rows of equations etc. to 100

Solve modelname using mip minimizing z;

- The command above issues the solve statement. The part after using defines the type of solver used.
- minimizing tells GAMS to minimize z, maximizing tells GAMS to maximize z.

Display z.m, x.l;

- The display statement controls how the variables of interest are displayed in the output.
- The letter after the dot represents the method with which the variable is displayed.
- The order of the commands is important and should roughly be as shown above.

The $ Operator

- Sometimes, a further adjustment is required to adequately express an equation.
- The command below includes the $, ord, card and and operators.

```
cn1(i,j)$((ord(i) le ord(j)) and (ord(j) le card(i) -1)).. x(i,j) =g= 1
```

- It is equivalent to the expression below.

$$x_{ij} \geqslant 1 \qquad\qquad \forall i \in I, \forall j \in J : i \leqslant j \leqslant s(I) - 1$$

- The $ operator signifies the logical "if" in GAMS while and represents the logical and.
- The card(j) command returns the cardinality of the set J.
- The ord(i) command gives the order of the element i, in the set I. The order of an element is the entry order on GAMS.
- Unless operation sare made to ensure otherwise, the sets in GAMS are ordered sets and therefore allow the use of the ord operator.
- Notice that, there is nothing numeric about declaring sets in GAMS, the names of the elements are stored as strings.

The default GAMS Example

	Beşiktaş	Kadıköy	Beyoğlu	Supply
Gebze	2.5	1.7	2.1	350
Çerkezköy	2.3	3.2	2.4	600
Demand	325	300	275	

- The table above represents the unit cost of supplies t from i (plants) to j (demand) and the total demand and supply at each point.
- We'd like to minimize our costs while adhering to the supply and demand values.

Col. Nick Fury is planning an espionage mission that requires subtlety and subterfuge.
The best personnel available for this mission and their abilities are given in the table below (next slide)
He aims to build the team with as few people as possible. He also needs to consider the previous romantic entanglements of the candidates.

- If Romanoff is picked for the team, then Murdock and Parker can't both be present in the team.
- The nature of the mission further necessitates that at most one of Parker, Drew and Lang to be chosen at a time.
- The team's aggregated ability in each category must meet the requirement values given below.

INT	DURA	SPEED	FIGHT
10	10	9	15

Name	INT	DURA	SPEED	FIGHT
Matt Murdock	3	2	2	5
Natasha Romanoff	4	3	3	6
Wade Wilson	2	4	4	6
Peter Parker	4	3	4	4
Jessica Drew	3	4	3	4
Scott Lang	4	5	3	4
T'Challa	5	3	2	5

If you get stuck...

- Try to figure out what GAMS is about by studying. You can do it.
- There are resources around the internet.
- Programming is mostly about reading the documentation of that language.
- `https://www.gams.com/fileadmin/community/contrib/doc/mccarlgamsuserguide.pdf`
- `https://www.gams.com/latest/docs/gams.pdf`
- Treat me only as a last resort.
- I won't be answering e-mails that are not sent to the adress I've provided(baslare@itu.edu.tr).