Power of GAMS

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Based on materials written by Gillig & McCarl and improved upon by many previous lab instructors

Special thanks to Mario Andres Fernandez
Outline

1. Why should we use GAMS?
2. GAMS Features
3. Model Library
4. Operating Tips
Why should we use GAMS?
Why should we use GAMS?

- Algebraic modeling
  - Context changes
  - Expandability - Expanding scope
  - Expandability - Augmenting existing models
Why should we use GAMS?

- **Algebraic modeling**
  - Context changes
  - Expandability - Expanding scope
  - Expandability - Augmenting existing models

- **Self-documenting nature**
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- Small to large modeling
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- GAMS solvers
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- **Self-documenting nature**

- **Small to large modeling**

- **GAMS solvers**

- **Model library**
Why should we use GAMS?

- Algebraic modeling
  - Context changes
  - Expandability - Expanding scope
  - Expandability - Augmenting existing models
- Self-documenting nature
- Small to large modeling
- GAMS solvers
- Model library
- Use by others
Context Changes

Example

SETS
  Process Production process
  /Corn Corn production
  Wheat Wheat production
  Cotton Cotton production
  /
  Resource Resource item used
  /Land Land used by process
  Labor Labor used by process
  /;
Context Changes

Example

SETS
Process Production process
/Corn Corn production
Wheat Wheat production
Cotton Cotton production
/
Resource Resource item used
/Land Land used by process
Labor Labor used by process
/

Example

SETS
Process Production process
/MakeChair Chair production
MakeTable Table production
MakeLamp Lamp production
/
Resource Resource item used
/Cap Max Production Capacity
Labor Labor used by process
/
Context changes but the model structure is the SAME! Only elements in sets are changed.
Context Changes

Example

TABLE ResourceUse(Resource, Process)

<table>
<thead>
<tr>
<th>Resource used</th>
<th>Corn</th>
<th>Wheat</th>
<th>Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Labor</td>
<td>6</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

PARAMETER Revenue(Process)

Revenues from process production

/Corn 109
/Wheat 90
/Cotton 115 /

Resource availability

/Land 100
/Labor 500 /;
Context Changes

Example

\[
\text{TABLE ResourceUse(Resource, Process)} \\
\text{Resource used} \\
\begin{array}{ccc}
\text{Corn} & \text{Wheat} & \text{Cotton} \\
\text{Land} & 1 & 1 & 1 \\
\text{Labor} & 6 & 4 & 8 \\
\end{array} \\
\]

\[
\text{PARAMETER} \\
\text{Revenue(Process)} \\
\begin{array}{c}
\text{Revenues from process production} \\
/\text{Corn} & 109 \\
\text{Wheat} & 90 \\
\text{Cotton} & 115 \\
\end{array} \\
\]

\[
\text{Resource availability} \\
\begin{array}{c}
/\text{Land} & 100 \\
\text{Labor} & 500 \\
\end{array} \\
\]

Example

\[
\text{TABLE ResourceUse(Resource, Process)} \\
\text{Resource used} \\
\begin{array}{ccc}
\text{MakeChair} & \text{MakeTable} & \text{MakeLamp} \\
\text{Cap} & 2 & 3 & 1.1 \\
\text{Labor} & 1 & 2 & 0.5 \\
\end{array} \\
\]

\[
\text{PARAMETER} \\
\text{Revenue(Process)} \\
\begin{array}{c}
\text{Revenues from process production} \\
/\text{MakeChair} & 11 \\
\text{MakeTable} & 10 \\
\text{MakeLamp} & 12 \\
\end{array} \\
\]

\[
\text{Resource availability} \\
\begin{array}{c}
/\text{Cap} & 12 \\
\text{Labor} & 5 \\
\end{array} \\
\]

Context changes but the model structure is the SAME! The only part modeled is the data.
Context Changes

Example

<table>
<thead>
<tr>
<th>TABLE ResourceUse(Resource,Process)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource used</td>
</tr>
<tr>
<td>Corn</td>
</tr>
<tr>
<td>Land</td>
</tr>
<tr>
<td>Labor</td>
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</tr>
<tr>
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<td>Cotton 115 /</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ResourceAvail(Resource)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource availability</td>
</tr>
<tr>
<td>/Land 100</td>
</tr>
<tr>
<td>Labor 500 /</td>
</tr>
</tbody>
</table>

Example

<table>
<thead>
<tr>
<th>TABLE ResourceUse(Resource,Process)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource used</td>
</tr>
<tr>
<td>MakeChair</td>
</tr>
<tr>
<td>Cap</td>
</tr>
<tr>
<td>Labor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PARAMETER Revenue(Process)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues from process production</td>
</tr>
<tr>
<td>/MakeChair 11</td>
</tr>
<tr>
<td>MakeTable 10</td>
</tr>
<tr>
<td>MakeLamp 12 /</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ResourceAvail(Resource)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource availability</td>
</tr>
<tr>
<td>/Cap 12</td>
</tr>
<tr>
<td>Labor 5/</td>
</tr>
</tbody>
</table>

- Context changes but the model structure is the SAME! The only part modified is the data.
Comparison

SETS Process  Production process
  / Corn   Corn production
  Wheat   Wheat production
  Cotton  Cotton production  /
Resource     Resource item used
  / Land   Land used by process
Labor       Labor used by process/;
TABLE ResourceUse(Resource,Process)  Resource
          Corn     Wheat     Cotton
Land       1        1        1
Labor      6        4        8 ;
PARAMETERS Revenue(Process)  Revenues
  / Corn    109
  Wheat    90
  Cotton  115 /
ResourceAvailable(Resource)  Resource availability
  / Land   100
Labor      500 / ;
VARIABLES
  Profit   Net income from process ;
POSITIVE VARIABLES
  Production(Process)  Production by crop ;
EQUATIONS
  Objective   Maximize farm income
  ResourceEq(Resource)  Resource Constraint ;
Objective..
  Profit =E=
    SUM(Process,Revenue(Process)*Production(Process)) ;
ResourceEq(Resource).
  SUM(Process,ResourceUse(Resource, Process)
    *Production(Process)) =L=
ResourceAvailable(Resource)  ;
MODEL ProfitMax /ALL;
SOLVE ProfitMax USING LP MAXIMIZING Profit ;

SETS Process  Production process
  / MakeChair  Chair production
  MakeTable  Table production
  MakeLamp  Lamp production  /
Resource     Resource item used
  / Land   Land used by process
Labor       Labor used by process/;
TABLE ResourceUse(Resource,Process)  Resource
          MakeChair MakeTable MakeLamp
Land       2        1        2
Labor      1        2        0.5 ;
PARAMETERS Revenue(Process)  Revenues
  / MakeChair  11
  MakeTable  10
  MakeTable  12 /
ResourceAvailable(Resource)  Resource availability
  / Land   12
Labor      5 / ;
VARIABLES
  Profit   Net income from process ;
POSITIVE VARIABLES
  Production(Process)  Production by crop ;
EQUATIONS
  Objective   Maximize farm income
  ResourceEq(Resource)  Resource Constraint ;
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  Profit =E=
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  SUM(Process,ResourceUse(Resource, Process)
    *Production(Process)) =L=
ResourceAvailable(Resource)  ;
MODEL ProfitMax /ALL;
SOLVE ProfitMax USING LP MAXIMIZING Profit ;
Expandability - Expanding Scope

Example

SETS
  Process   Production process
  /Corn     Corn production
  Wheat     Wheat production
  Cotton    Cotton production
  Soybean   Soybeans production /
  Resource  Resource item used 
  /Land     Land used by process
  Labor     Labor used by process/

TABLE ResourceUse(Resource,Process) Resource used
  Corn   Wheat   Cotton   Soybean
  Land   1       1       1       1
  Labor  6       4       8       4 ;

PARAMETER
  Revenue(Process) Revenues from process production
  /Corn  109
  Wheat  90
  Cotton 115
  Soybean 95 /
  ResourceAvail(Resource) Resource availability
  /Land  100
  Labor  500 /;

- Instead of growing 3 crops, now a farmer also wants to grow soybeans. One needs only to modify an element in Process set, ResourceUse table, and Revenue parameter.
- Other data and the model structure remains the SAME!
Expandability - Augment Existing Models

Example

PARAMETER
Revenue(Process) Revenues from process production
/Corn 109
/Wheat 90
/Cotton 115
/Soybean 95 /
ResourceAvail(Resource) Resource availability
/Land 100
/Labor 500 /
MinLand(Process) Minimum land requirement
/Corn 0
/Wheat 10
/Cotton 0
/Soybean 0 /;

EQUATIONS
Objective Maximize farm income
ResourceEq(Resource) Resource constraint
MinLandReq(Process) Minimum land requirement ;

MinlandReq(Process).. ResourceUse(“Land”,Process)*Production(Process) =g= MinLand(Process) ;
Self-documenting Nature

GAMS allows one to add explanatory text when naming SETS, PARAMETERS, TABLES, VARIABLES, EQUATIONS, but it is a good habit to name them with easy-understanding words instead of simple letters.

```
Eq1..   
   X1 =E= SUM(S1,Y1(S1)*X2(S1)) ;

Eq2(S2)..
   SUM(S1,Y3(S2,S1)*X2(S1)) =L= Y2(S2)  ;
```

```
Objective..
  Profit
  =E=
  SUM(Process,Revenue(Process)*Production(Process)) ;

ResourceEq(Resource)..
  SUM(Process,
     ResourceUse(Resource,Process)*Production(Process))
  =L=
  ResourceAvailable(Resource) ;
```
Self-documenting Nature

- GAMS allows one to add explanatory text when naming SETS, PARAMETERS, TABLES, VARIABLES, EQUATIONS, but it is a good habit to name them with easy-understanding words instead of simple letters.

- Which form between the examples below clearly shows the context of itself?

```
Eq1..
   X1 =E= SUM(s1,y1(s1)*x2(s1)) ;

Eq2(s2)..
   SUM(s1,y3(s2,s1)*x2(s1)) =L= Y2(s2) ;

Objective..
   Profit
   =E=
   SUM(Process,Revenue(Process)*Production(Process)) ;

ResourceEq(Resource)..
   SUM(Process,
       ResourceUse(Resource,Process)*Production(Process))
   =L= ResourceAvailable(Resource) ;
```
Self-documenting Nature

- Always remember commenting your code. Comments can not only help others who read your code, but also help yourself for future references.
- Comment a line: asterisk “*”
- Comment multiple lines: put comments between $ONTEXT and $OFFTEXT

```plaintext
* this shows how * is used

$ONTEXT
  this shows how $ontext $offtext is used
  Lines are in between are considered by GAMS as text comments
$OFFTEXT

ResourceEq( Resource ) ..
  SUM ( Process,
    ResourceUse( Resource, Process ) * Production( Process ) )
  =L=
  ResourceAvailable( Resource ) ;
```
Small to Large Modeling

- GAMS expandability allows the same model structure, calculations, and report writing to be used with SETS with few elements vs. SETS with many items.

```
SETS
Stocks          POTENTIAL INVESTMENTS /BUYSTOCK1*BUYSTOCK100 /
SmallStocks(Stocks) POTENTIAL INVESTMENTS /BUYSTOCK1*BUYSTOCK2 /
EVENTS          EQUALLY LIKELY RETURN SCN /EVENT1*EVENT2 /

INVESTAV..
   SUM(SmallStocks, PRICES(SmallStocks) * INVEST(SmallStocks))
   =L=  FUNDS ;
```
Small to Large Modeling

- GAMS expandability allows the same model structure, calculations, and report writing to be used with SETS with few elements vs. SETS with many items.

- Using a small data set allows up to examine the model structure and function easier and better. Then later one can use the same algebra for a large problem.
  - Use subsets
  - Use small group of scenarios (1 or 2)
  - Use aggregate regions

```
SETS
  Stocks           POTENTIAL INVESTMENTS /BUYSTOCK1*BUYSTOCK100 / 
  SmallStocks(Stocks) POTENTIAL INVESTMENTS /BUYSTOCK1*BUYSTOCK2 / 
  EVENTS           EQUALLY LIKELY RETURN SCN /EVENT1*EVENT2 / ;

INVESTAV.. 
  SUM(SmallStocks, PRICES(SmallStocks) * INVEST(SmallStocks)) 
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```
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SETS
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INVESTAV.
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  =L=  FUNDS;
```
GAMS Solvers

- GAMS integrates many solvers that can solve most optimization problems.
- Specify the solver in the SOLVE statement

Example

SOLVE MyProblem using LP maximizing Z;
SOLVE MyProblem using MIP maximizing Z;
SOLVE MyProblem using NLP maximizing Z;
GAMS Solvers

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- Specify the solver in the SOLVE statement

Example

SOLVE MyProblem using LP maximizing Z;
SOLVE MyProblem using MIP maximizing Z;
SOLVE MyProblem using NLP maximizing Z;
Model Library

- GAMS has been used as a standard in optimization models in many fields.
- Models exist from experienced users that address similar problems.
- Textbook
- Fixing Models Book
- GAMS Library
- GAMS Newsletter
Model Library in GAMS

- Models are available through the GAMS library which is directly included in the IDE.
Use by Others

- Two files: `data.gms` and `mymodel.gms`.
Use by Others

- Two files: `data.gms` and `mymodel.gms`.
- Create a “t” folder (or any other names) under the project directory.

```
SETS
Crop   Crop production
  /Corn   Corn production
  Wheat   Wheat production
  Cotton  Cotton production /
Resource Resource item used
  /Land   Land used by crop
  Labor  Labor used by crop /;

TABLE ResourceUse(Resource,Crop) Resource use
  Corn  Wheat  Cotton
  Land   1      1      1    ;
  Labor  6      4      8    ;

PARAMETERS
Revenue(Crop) Revenues
  /Corn   109
  Wheat   90
  Cotton  115 /
ResourceAvailable(Resource) Resource
  /Land   100
  Labor  500 /;
```
Use by Others

- Two files: `data.gms` and `mymodel.gms`.
- Create a “t” folder (or any other names) under the project directory.
- Type the content in the red box before running `data.gms`. 
Use by Others

- Two files: `data.gms` and `mymodel.gms`.
- Create a “t” folder (or any other names) under the project directory.
- Type the content in the red box before running `data.gms`.
- When finished running `data.gms` which includes all of data, GAMS will save all the information in `\t\a1` where it is ready to be used.
To solve the model, GAMS retrieves information on data that was saved in \texttt{\t\a1}.
Use by Others

- To solve the model, GAMS retrieves information on data that was saved in \( t/\text{a1} \).
- Type the content in the red box before running `mymodel.gms`.

```gams
VAR
  Profit Net income from crops;
POSVAR
  Production(Crop) Production by crop;
EQUATIONS
  Objective Maximize farm income;
  ResourceEq(Resource) Resource Constraint;
  Objective..
  Profit=E= SUM(Crop, Revenue(Crop)*Production(Crop));
  ResourceEq(Resource).
  SUM(Crop, ResourceUse(Resource,Crop) * Production(Crop))
  =L= ResourceAvailable(Resource);
MODEL FarmIncome /ALL/;
SOLVE FarmIncome USING LP MAXIMIZING Profit;
```
To solve the model, GAMS retrieves information on data that was saved in `\t\a1`.

Type the content in the red box before running `mymodel.gms`.

When finished solving `mymodel.gms`, GAMS will save all information including solutions in `\t\a2` where it is ready to be used later, say, report writing.
Heads On 3

- Fix errors in Handson3error.gms and send an *electronic* copy of the correct *.gms file via email.
- Hand in a *hard* copy of *.lst file (from “Solution Report” to the end).