A generic decomposition approach for equations in GAMS models

Wolfgang Britz
Institute for Food and Resource Economics, University Bonn
Outline

• Why decomposition?
• Approaches to decomposition
• Generic approach based on GAMS plus Java (GGIG interface package)
  – Methodology
  – Required output from GAMS
  – Work with the „Equation and Variable Viewer“
Why decomposition?

• If a variable on the LHS depends on several variables on the RHS, it might not be easy to understand what drives the change of the LHS

• Examples:
  – Behavioral equations with own- and cross price effects
  – Profit changes depend on changes of multiple netputs quantities and prices

• Understanding these changes often crucial for policy analysis (and during debugging)
Approaches to decomposition

• Write case specific post-model code:
  – e.g. used in CAPRI for behavioral equations
  – e.g. used in GTAP to decompose welfare changes
  ++ flexible, can track changes across equations or summarize effects of blocks of variables (e.g. all cross price effects)
  -- coding and maintenance efforts

• Generic approach
  – Requires information from solver on Jacobian
  ++ Model independent
  -- Restricted to one equation
Generic approach in GAMS and Java

Change in LHS variable $x$ approximately equal to changes in RHS variables $y$ weighted with their Jacobian entries.

$$x = f(y)$$

$$\Delta x \approx \sum_i \left( \frac{\partial x}{\partial y_i} \right) \Delta y_i$$

CONVERT utility from GAMS delivers variable levels before and after the solve to calculate differences in $x$ and $y$.
In order to easier digest the information, contribution of variables $y$ is expressed as % contribution to change in $x$, entries add up approximately to 100%.

\[
\Delta x \approx \sum_i \frac{\partial x}{\partial y_i} \Delta y_i \\
\frac{\Delta x (y_i)}{\Delta x} \% \approx \frac{\partial x}{\partial y_i} \Delta y_i \div \Delta x 100
\]

Approximate percentage share of change in $x$ stemming for the change in each $y$. 

**Generic approach in GAMS and Java**
Application to your own model

• Solve your model with CONVERTD (a “pseudo solver”) before and after the actual model solve, variables should be at benchmark (no shock)

• Use the “Equation and Variable viewer” built in GGIG to decompose (does not require that your model runs under the interface)
Application to your own model

```gams
$ifthen1.after "%1"=""after"
$onecho > convertd.opt
  gams %gamsDocDir%\convert_gtap8.gms
dict %gamsDocDir%\convert_gtap8.txt
jacobian %gamsDocDir%\convert_gtap8_after.gdx
$offecho
  gtap.optfile = 1;
$else.after
$onecho > convertd.opt2
  jacobian %gamsDocDir%\convert_gtap8_before.gdx
$offecho
  gtap.optfile = 2;
$endif.after
  gtap.holdfixed = 0;
  option nlp=convertd;
  solve gtap using nlp minimizing dummy ;
  gtap.holdfixed = 1;
);
$endif.CONVERT
```
Equation and Variable Viewer

• Uses CONVERT output to show equations as generated by GAMS:
  – parameters are converted to numerical constants
  – individual instances are shown, reflecting e.g. $ operators to skip equations and variables
  – selection by variable / equation, filters for domains
  – if GDX with all symbols in model is present, parameters etc. can be easily inspected
  – link to model code possible
Equation and Variable Viewer

- Open Equation and Variable Viewer from model GUI based on GGIG
Equation and Variable Viewer

GDX from execute_unload after model solve (all symbols)

Files generated by CONVERT (variable levels, Jacobian, linearized equations)

Main GAMS file of your model

Ref file from running for model (allows e.g. to find included files)
Equation and Variable Viewer

Load the files into the viewer ... that might take up to minute, depending on how large the model is
Equation and Variable Viewer

Select an equation
Equation and Variable Viewer

The viewer will an equation as seen below, parameters become numerical constants

Equation instance

\[ \text{arenteq(EU\_25, shock)} \text{ "Aggregate rate of return " } \]

\[-1.077*\text{pft(EU\_25, Capital, shock)} \{-0.003328, 0.003328, -0.3328\}*(1.0\]
\[-\text{kappaf(EU\_25, Capital, shock)} \{0.0\})\]
\[+0.1349*\text{arent(EU\_25, shock)} \{-0.02467, -0.003328, -100.0\}% = E=0.0; \]

- Variable in equation
- Change in levels
- Change times Jacobian
- Contribution to change of LHS
- Variable with Jacobian==1 (possibly LHS)
Equation and Variable Viewer

A more complex example with non-linearities

\[
xdeq(EastAsia,\text{TransComm-c, hhsld, shock}) \ "Agents demand for domestic goods " \ .
\]

\[
-7.57E-4\times
\]

\[
pa(EastAsia,\text{TransComm-c, hhsld, shock})\{0.00965, -0.0162, 1290.0\%}\bigg/
\]

\[
ps(EastAsia,\text{TransComm-c, shock})\{0.0101, 0.0169, -1350.0\%}\bigg(1.0
\]

\[
+\text{dintx}(EastAsia,\text{TransComm-c, hhsld, shock})\{0.0\}
\]

\[
+\text{itxshft}(EastAsia, hhsld, shock)\{0.0\})
\]

\[
\bigg)
\]

\[
x^*\text{a}(EastAsia, \text{TransComm-c, hhsld, shock})\{3.01, -0.00202, 161.0\%\}
\]

\[
= 7.55E-4\times d(EastAsia, \text{TransComm-c, hhsld, shock})\{1.66, 0.00125, 0.141\%\}=E=0.0;
\]

Note: The number of significant digits shown can be changed.
Summary

• Generic approach applicable to any GAMS model to decompose change on LHS of equation to changes of variables on the RHS
• Minimal coding in efforts in GAMS needed
• Integrated in viewer which offers additional information
• Main dis-advantage is that the approach cannot track changes across a set of equations