AnalyseGE: Software Assisting Modellers in the Analysis of Their Results

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Abstract

When modellers carry out an application with a general equilibrium model, they are faced with the task of explaining their results. This requires them to identify and quantify the main mechanisms of the model which are producing the results. To do this, they must bring together details of the equations of the model, the base data, consequences of that data (totals etc) and the simulation results (percentage changes etc).

AnalyseGE is a software tool which is aimed at assisting modellers to move quickly between these different information sources. The AnalyseGE interface gives users "point and click" access to the equations of the model, the data, and the simulation results. In particular a modeller can click on any equation and ask the software to group the terms into different natural parts, and give the numerical values of each term. This greatly reduces the burden associated with analysing simulations, and offers the potential for significantly boosting the productivity of applied general equilibrium modellers.

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[4] The first version of this paper, dated June 2000, was presented to the Third Annual Conference on Global Economic Analysis. This version is based on the revised version dated July 2001. It contains modifications to sections 2 and 3 in which the first application is solved using version 6.1 (August 2001) of GTAP.TAB.

1   Introduction

When modellers carry out an application with a general equilibrium model, they are faced with the task of explaining their results. This requires them to identify and quantify the main mechanisms of the model which are producing the results. To do this, they must bring together details of the equations of the model, the base data, consequences of that data (totals etc) and the simulation results (percentage changes etc). Often these are found in different places on the computer (different files etc), and a time-consuming part of the task is moving between the different sources of information.

AnalyseGE is a software tool which is aimed at assisting modellers to move quickly between these different information sources. It can be used to analyse the results of any simulation carried out using Release 7.0 (or later) of GEMPACK [see Harrison and Pearson (1996)]. The AnalyseGE interface gives users "point and click" access to the equations of the model, the data and consequences, and to the simulation results. In particular a modeller can click on any equation and ask the software to group the terms into different natural parts, and give the numerical values of each term. A brief tour of the main features of AnalyseGE can be found in section 2.

In this paper we illustrate how the software can assist with the analysis of the numerical results of two applications with the GTAP model [see Hertel (1997)]. (These applications are discussed in sections 3 and 4 of the paper.) The first application is a rather simple one in which the model is highly aggregated and only one tariff rate is shocked. This is intended to be illustrative and its simplicity will facilitate its live presentation. The second application is a more typical one in which there are more sectors and regions to take account of.

An alternative hands-on introduction to AnalyseGE based on a simulation with Stylized Johansen model can be found in section 6.1 of the Release 8.0 version of GEMPACK Document GPD-8 [Harrison and Pearson (2002)].

In section 5 we describe a few features of AnalyseGE which have not been mentioned previously. In section 6 we describe how you can obtain this tool (at no cost) and install it on your computer. Our conclusions are in section 7. Section 8 is a somewhat technical appendix.

2   Quick Look at Some of the Features of AnalyseGE

This section will give you a brief tour of the main features of AnalyseGE. As in the rest of this paper, we assume here that you have installed AnalyseGE on your computer, and are carrying out on your computer the steps described in this paper.[5] If you have not already installed AnalyseGE, please do so now, following the instructions in section 6.

2.1   Loading the Example Simulation Results

In order to see how AnalyseGE works, you need to load the results of a simulation (that is, load a Solution file).

There are two ways you can do this, as described below. The first relies on the files supplied when you installed AnalyseGE. The second is appropriate if you are working with RunGTAP.

1.   When you install AnalyseGE, it comes with examples. In subdirectory **GTAP1** of the directory in which AnalyseGE is installed there should be files **gtmseufg.sl4** and

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[5] In this document, to save space, we assume that the reader is familiar with ViewHAR and TABmate, but describe the AnalyseGE interactions in detail.

gtmseufg.slc.[6]

Start AnalyseGE running by double-clicking on its icon. Click on the **Select/Change** button and select the Solution file **GTMSEUFG.SL4** (in the subdirectory GTAP1 of the directory in which AnlayseGE is installed). This Solution file contains the results of the GTAP application you will analyse in section 3.

2. If you are working with RunGTAP,[7] you can load the results as follows.

Start RunGTAP running, change to Version ACORS3X3, go to the Solve page and **Load experiment** called **TMSeufg**. Then click on the **Solve** button.

When the simulation has finished (and you have clicked OK), click on *View | Results using AnalyseGE* under the View menu.[8] This is also the simulation you will analyse in section 3.

2.2   Hands-on Introduction to Some of the Features of AnalyseGE

AnalyseGE has 3 forms (or windows). The main one you will use is the TABmate form which will contain the TABLO Input file[10] (usually called GTAP.TAB[11]) for the GTAP model. [AnalyseGE extracts this from the Solution file.] Much of the analysis can be done by selecting and clicking on equations in the TABLO Input file, as you will see below. The other two forms are the ViewHAR form (which will show the numerical results of various calculations) and the AnalyseGE form (which is the form shown each time AnalyseGE starts).

Go to the TABmate form (which is probably already the top one of the three forms associated with AnalyseGE).

AnalyseGE makes it easy to see the values of any variable or coefficient.

To see this, find the declaration of variable **qo** (for example, using the Search menu). **Left-click** anywhere in this declaration. Then **right-click** anywhere on the TABmate form.[12] A menu will appear. Select the option **Evaluate this Variable**. A ViewHAR window will appear to show the values of all components of variable qo.

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[6] These files will only be present if you have installed version 2.41 (October 2002) or later of AnalyseGE. [See menu item *Help | About* on the AnalyseGE form (not the TABmate or ViewHAR form) to find which version of AnlayseGE you are running.] If you are running an earlier version of AnalyseGE, or if you do not find these files, download the latest version of AnalyseGE from the GEMPACK web site (see section 6).

[7] We assume in this document that you are using Version 3.10 (June 2001) or later of RunGTAP.

[8] If the menu item **Results using AnalyseGE** is not visible (or is greyed out), this is because of a small bug in RunGTAP. You can either download a bug fix for RunGTAP from the GTAP web site or (probably easier), load the example simulation as described in the alternative point 1 in the text.

[9] This file will be in the subdirectory GTAP1 of the directory in which you installed AnalyseGE – see section 6.

[10] The TABLO Input file contains the equations of the model written in algebraic form [see Harrison and Pearson (1996).]. [It is similar to the .GMS file used with GAMS.]

[11] AnalyseGE may call this something like AN1.TAB. This file is put into a temporary directory after AnalyseGE extracts it from the Solution file.

[12] Your mouse has two (or possibly three) buttons. Left clicking uses the left-hand one, while right-clicking uses the right-hand one. In this document, we often just say "click" when we mean left-click. But we will not abbreviate "right-click".

For example, you can see the percentage change in the output of food in EU in this simulation. To get back to the TABmate window, select menu item *Front | Bring TABmate to the front* from ViewHAR's main menu.[13]

To see the corresponding feature for Coefficients, go to the top of the TABmate form (click there) and then find the declaration of coefficient **VDFA(i,j,r)** . First left-click on this and then **right-click** and select the menu option **Evaluate this Coefficient**. Again the ViewHAR window will appear. As usual with ViewHAR, because this coefficient has 3 indices (i,j,r) you will probably see the values summed over the third index r in REG. You can manipulate the drop-down combo boxes in the top right-hand corner of the ViewHAR form to see, for example, the value at agents' prices of domestic purchases of food by the Manufacturing (mnfcs) firms in Sub-Saharan Africa (SSA).

You can also find the values of variables or coefficients from any equation or formula where they appear. To see this, return to the TABmate form, go to the top and then find the equation **MKTCLTRD_NMRG**. **Left-click** on the qo term on the left-hand side (for example, between the "q" and the "o"). Then **right-click** and select menu option **Evaluate (selection or coeff/var at cursor)**. Again the ViewHAR form will appear and you will see the values of variable qo.

AnalyseGE can evaluate expressions you select with your mouse.

To see this, return to the TABmate form and **select with your mouse** the expression **SHRDM(i,r)*qds(i,r)** .[14] Now **right-click** and select menu option **Evaluate (selection or coeff/var at cursor)**. Again the ViewHAR form will appear and you will see the values of the expression SHRDM(i,r)*qds(i,r) for each i in NMRG_COMM and each r in REG.

You can also enter expressions to be evaluated in the memo on the AnalyseGE form.

To see this, bring the AnalyseGE form to the front via menu item *Front | Bring AnalyseGE to front* . Then click on the **Clear** button to clear the memo. Now type

VDM(i,r)*qds(i,r) ;

into this memo. [Don't forget the final semi-colon **;** .] Now click on the **Evaluate** button. Yet again the ViewHAR form will appear and show the values of this expression for each i in TRAD_COMM and each r in REG.

AnalyseGE has more sophisticated features.

For example, it is able to decompose the terms on the right-hand side of a formula or equation and show you the values of all terms. We will not illustrate this here since you will see plenty of examples in the analysis below.

If you click and then right-click on various statements in the TABmate form, you often find more sophisticated options than the simple "Evaluate" one in the pop-up menu.

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[13] That is, first click on *Front* in the main menu, then select option *Bring TABmate to the front* from the menu which appears.
[14] That is, left-click just to the left of the "S" in SHRDM and drag with your mouse until all of this expression is highlighted.
The numbers that you see are contributions to the qo result on the left-hand side since they are shares (SHRDM) times percentage changes (qds).

The options that you see depend on the type of statement you clicked on. For example, if you click again on the *declaration* of variable **qo** and then right-click, you might like to see what happens if you select menu option **Evaluate Linear and Levels results (toggle first)**.

AnalyseGE lets you know which variables are exogenous and which are endogenous. Exogenous variables are coloured **red**; those not shocked are shown in italics and those shocked are bolded. Endogenous variables are **green** while variables which have been substituted out are coloured **grey** and shown in italics (which indicated that results are not available). If a variable has some components exogenous and some endogenous, the variable is coloured **purple**. Omitted variables are shown as red italics to indicate they have not been shocked.

For example, find the equation **MKTCLENDWM**. You can see from the colouring of the variables that **endwslack** is exogenous and not shocked, that **qfe** is endogenous and that some components of **qo** are exogenous and some are endogenous.

If these colourings are not visible, go to the AnalyseGE window via menu item *Front | Bring AnalyseGE to front* . Click on the *Options* menu item. You will see two items in this menu relating to colouring, namely **Distinguish Exog/Endog in TABmate** and **Do not distinguish Exog/Endog in TABmate**. Colouring will only be shown if the first of these is checked. If not, select it, and you will see from the message that the colours will be shown next time you load a Solution file into AnalyseGE.

You can easily find all statements in the TABLO file involving any coefficient, variable or set, using the **Glossary** feature from TABmate.

For example, find the declaration of variable **tms** in the TABmate form and click somewhere in the middle of the letters **tms** with your mouse. Then click on the **Gloss** button (which is near the top of the TABmate form – it is a large capital G). You will see that the variable **tms** occurs in just three statements in the TABLO file, namely those at lines 1704 (the declaration), line1725 (the equation MKTPRICES), and at line 1782 (the equation TIMPRATIO). If you click on the red **~ 1725** beside the equation MKTPRICES in the glossary window, you will jump straight to that equation. [If you are running RunGTAP and see a different line number next to the equation MKTPRICES, click on whatever line number is shown in red next to the equation MKTPRICES.[15]]

2.3 Looking at the Values in the ViewHAR Form

Each time you evaluate a variable, coefficient or expression, AnalyseGE adds two headers to the ViewHAR form being built up. The header you always see is the one containing the values. There is also a second header which contains the full expression evaluated. To see this, bring the ViewHAR form to the front and click on the *Contents* menu item. You will see headers with names **E001, R001, E002, R002** and so on. These are in pairs: the **Exxx** header contains the expression and the **Rxxx** header contains the values. For example, if you double-click on the header **E003** you will see the expression

(All,i,NMRG_COMM)(All,r,REG)   SHRDM(i,r)*qds(i,r) ;

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[15] The description here assumes that you are using Version 6.1 of GTAP.TAB and associated GTAP.EXE (etc). If your GTAP.TAB file is Version 6.0 (April 2001), you should go to the GTAP web site and download the Version 6.1 files (including new GTAP.EXE etc) since Version 6.0 contained a couple of errors which could produce incorrect results in some cases.

you evaluated before. If you go back to the Contents page of ViewHAR, and double-click on the associated header **R003**, you will see the values of this expression.

So you can always go to the Contents page in ViewHAR to review the expressions and values already evaluated. When you exit from AnalyseGE, you will be asked if you want to save the Header Array file containing these expressions and values.

When you are new to AnalyseGE, it is always a good idea to check the expression evaluated in this way to make sure that AnalyseGE is evaluating what you expect.

2.4   What Values Does AnalyseGE Show ?

When you use AnalyseGE to look at the values of variables, you see the simulation results (that is, the percentage change results from the simulation).

When you use AnalyseGE to look at the values of Coefficients, *you see the pre-simulation values*. For parameters (such as the Armington ESUBM values), these do not change during the simulation. But the values of shares (such as the MSHRS values in section 3.2.1 below) may change during the simulation. For example, since imports of food from SSA into EU have increased more than imports of food from other regions into the EU, the post-simulation value of MSHRS("food","SSA","EU") will be larger than its pre-simulation value.[16]

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[16] With Release 8.0 (or later) GEMPACK programs, you can choose to see the post-simulation values, or the average of the pre-simulation and post-simulation values. See section 1.6 of the Release 8.0 version of GEMPACK Document GPD-1 [Harrison and Pearson (2002)].

3 First Application – Eliminating One Import Tariff

In this section we show you how you can use AnalyseGE to analyse the results of the simulation you loaded into AnalyseGE in section 2. The simulation is as follows.

> The data is a 3x3 aggregation of the version 4 preliminary data.[17] The aggregation recognises three commodities **food**, manufactures (**mnfcs**) and services (**svces**) and three regions, Sub-Saharan Africa (**SSA**), European Union (**EU**) and Rest of the World (**ROW**). The simulation is one in which the import tariff on food from Sub-Saharan Africa to the European Union is completely eliminated. The shock is –11.5375 per cent to the power of this import tariff.[18]

Below we describe how AnalyseGE can be used to analyse some of the results of this application. We aim to give sufficient detail to enable you to follow the analysis on your computer.[19]

3.1 Price Change at EU Border

The shock is a reduction by 11.5375 percent in **tms("food","SSA","EU")**. The most obvious consequence of this shock is to reduce the price paid in the EU for imports of food from SSA. This is the model result for **pms("food","SSA", "EU")**.

The relevant equation is the one called **MKTPRICES**, which reads[20]

```
(All,i,TRAD_COMM)(All,r,REG)(All,s,REG)
        pms(i,r,s) = tm(i,s) + tms(i,r,s) + pcif(i,r,s) ;
```

First find this equation in the TABmate form (for example, using the Search menu). To see the value of the import price pms("food","SSA","EU"), **left-click** on this (say between the "p" and the "m") and then **right-click** anywhere on the TABmate form. A menu will appear. Select the option **Evaluate (selection or coeff/var at cursor)**. A ViewHAR window will appear to show the values of all components of variable pms. Manipulate the drop-down combo boxes in the top right-hand corner so that you can see the value of pms("food","SSA","EU"); it should be –9.65.[21] To get back to the TABmate window, select menu item *Front | Bring TABmate to the front* from ViewHAR's main menu. Then repeat

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[17] The aggregation is the one known as ACORS3X3 in the current version of RunGTAP.

[18] This application is the one analysed in the "Johansen Lab" on day 3 of recent GTAP Short Courses. The analysis in this paper follows similar steps. However the analysis in this paper is based on the accurate solution results (using Gragg 2,4,6 steps) whereas the Short Course analysis is based on the approximate Johansen solution.

[19] Here, to save space, we assume that the reader is familiar with ViewHAR and TABmate, but describe the AnalyseGE interactions in detail.

[20] **pms(i,r,s)** is the price of imported commodity i from source r in region s. **pcif(i,r,s)** is the CIF price of this. **tms(i,r,s)** is the power of the import tariff (that is, 1 plus the *ad valorem* rate) while **tm(i,s)** is the power of the import tariff on all imports of i into region s (irrespective of the source region). The variables pms, tm, tms and pcif actually represent the percentage changes in the corresponding levels quantities. The equation is a linearised equation. In order to solve the underlying levels of the model accurately, GEMPACK solves the associated linearised equations several times [see Harrison and Pearson (1996)]. This means that the linearised equations are NOT satisfied exactly by the simulation results (as you will see). However they are usually satisfied approximately.

[21] For example, manipulate the drop-down combo boxes so that they read (from left to right) **food**, **SSA**, **All REG**.

to find the values of tm("food","EU"), tms("food","SSA",EU") and
pcif("food","SSA","EU"). The first should be zero (it is exogenous and not shocked), the
second should be (approximately) –11.54 (the shock) and the third should be 2.13.[22] Notice
that the price of imports of food from SSA in EU does not fall by the full amount (11.54%) of
the shock but by a smaller amount. This is because the CIF price of food from SSA to EU
rises by a small amount (2.13%); this rise is due to the price rise for food produced in SSA
which you can analyse later.

The above illustrates one of the main features of AnalyseGE. You can click anywhere in an
equation and see the values of the variables in the equation.

3.2   Effect on Food Imports into EU

In GTAP, imports are bundled together at the border to make a composite imported
commodity. This is done via a CES nest.

In this section you will analyse the changes in the price and quantity of food imported into the
EU. That is, you will analyse the results for **pim("food","EU")** and **qim("food","EU")**.

3.2.1   Price of Food Imports into EU

Firstly you will wish to look at the price part of this nest.[29]

The relevant price variable is **pim**. To find the equations containing this variable, find the
declaration of   **pim** in the TABmate form. Click on the name **pim** and then click on the
Gloss button (marked with a large capital G near the top of the TABmate form). You will see

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[22] Notice that, as expected, the linearised equation MKTPRICES is not satisfied exactly by
these results. The LHS is –9.65 while the RHS is equal to -11.54+2.13 = -9.41. But, as
expected, the linearised equation is satisfied approximately. This apparent discrepancy is
discussed in more detail in Appendix 1 – see section 8.

[23] The aggregation is the one known as ACORS3X3 in the current version of RunGTAP.

[24] This application is the one analysed in the "Johansen Lab" on day 3 of recent GTAP Short
Courses. The analysis in this paper follows similar steps. However the analysis in this paper is
based on the accurate solution results (using Gragg 2,4,6 steps) whereas the Short Course
analysis is based on the approximate Johansen solution.

[25] Here, to save space, we assume that the reader is familiar with ViewHAR and TABmate,
but describe the AnalyseGE interactions in detail.

[26] **pms(i,r,s)** is the price of imported commodity i from source r in region s. **pcif(i,r,s)** is the
CIF price of this. **tms(i,r,s)** is the power of the import tariff (that is, 1 plus the *ad valorem*
rate) while **tm(i,s)** is the power of the import tariff on all imports of i into region s
(irrespective of the source region). The variables pms, tm, tms and pcif actually represent the
percentage changes in the corresponding levels quantities. The equation is a linearised
equation. In order to solve the underlying levels of the model accurately, GEMPACK solves
the associated linearised equations several times [see Harrison and Pearson (1996)]. This
means that the linearised equations are NOT satisified exactly by the simulation results (as
you will see). However they are usually satisfied approximately.

[27] For example, manipulate the drop-down combo boxes so that they read (from left to right)
food, **SSA**, **All REG**.

[28] Notice that, as expected, the linearised equation MKTPRICES is not satisfied exactly by
these results. The LHS is –9.65 while the RHS is equal to -11.54+2.13 = -9.41. But, as
expected, the linearised equation is satisfied approximately. This apparent discrepancy is
discussed in more detail in Appendix 1 – see section 8.

[29] If you are still on the ViewHAR form, return to the TABmate form via *Front | Bring
TABmate to the front* .

that this variable occurs in several equations. The equation which "explains" variable pim probably has this variable on the left-hand side. Can you find such an equation? The relevant equation is **DPRICEIMP**, so click on the line number beside this equation in the glossary window to jump to it. You will see that the equation is[30]

```
pim(i,s) = SUM(k,REG, MSHRS(i,k,s) * [pms(i,k,s)-ams(i,k,s)] ) ;
```

Here the MSHRS are the market shares of the different regions (SSA, EU and ROW) in total imports of commodity i into region s. To see the values of the terms MSHRS*[pms-ams], select this expression with your mouse in the TABmate form.[31] Then right-click and you will see a menu. Select the option **Evaluate (selection or coeff/var at cursor)** . You will see that the values of interest (namely when i=food and s=EU) are -0.39 (k=SSA), -0.09 (k=EU)[32] and -0.003 (k=ROW).[33]

You can also click on the LHS term pim(i,s) and then right-click to see the value of pim("food","EU"), which is –0.58. [Notice that the 3 terms on the RHS of the equation above add to –0.48 which is approximately this value of –0.58. An explanation of the difference can be found in Appendix 1 in section 8.2.] Why is the fall in pim("food","EU") so small when pms("food","SSA","EU") falls by much more (over 9%)? The equation above shows that the share MSHRS("food","SSA","EU") multiplies this; the value of this share is just 0.04. [You can see the MSHRS values in the same way as you have already seen the values of simulation results. Click anywhere inside MSHRS and the right-click and choose "Evaluate ..".]

3.2.2 Quantity of Food Imports from SSA into EU

The second part of the CES nest is the equation **IMPORTDEMAND** which dictates the percentage change in import demand for product i, imported from region r into region s:

```
qxs(i,r,s) = -ams(i,r,s) + qim(i,s)
                - ESUBM(i) * [pms(i,r,s) - ams(i,r,s) - pim(i,s)]
```

The form of this demand equation is quite common in CGE modelling. The qim term on the right-hand side is the so-called "expansion effect". This dictates the increase in demand for imports from a given source, based on the overall increase in composite imports. If relative prices are unchanged, then this is the end of the story. The second term on the right-hand side of this equation is the "substitution effect". It captures the tendency to source products from the cheapest source. ESUBM is the elasticity of substitution among alternative import sources, and the negative of this value pre-multiplies the percentage change in the ratio of source-specific price to the average price of imports. When one is conducting analysis of simulation results, it is often quite important to know how much of the change in import

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[30] Here and later, we omit the quantifiers which indicate over which sets the indices range. These sets will usually be obvious. In this case, the quantifiers are (All,i,TRAD_COMM) (All,r,REG).

[31] That is, click with your mouse (use the left mouse button) anywhere within "MSHRS", then hold the mouse button down and drag it to the right until it is inside the "pms" part. The relevant letters will be highlighted. [Then let go of the mouse.]

[32] You may be surprised to see imports of food from the EU into itself. This is because (in this aggregation of the GTAP data) the EU is a composite region obtained by combining several sub-regions which have trade between themselves.

[33] For example, manipulate the drop-down combo boxes so that they read (from left to right) **food**, **all REG**, **EU**. Notice from the expression shown near the bottom of the ViewHAR form that the quantifiers in the expression shown are in the order (All,i,TRAD_COMM)(All,k,REG)(All,s,REG).

demand is due to the expansion effect, and how much is due to the substitution effect. The "intelligent" decomposition tool in AnalyseGE makes this easy to do.

Consider, for example, the percentage change in imports of food from SSA into EU. You can use AnalyseGE (as in the section above) to see that the **qxs("food","SSA","EU")** result is a rather large 56.90.

In order to decompose the RHS of the equation above, click anywhere on this equation in the TABmate form. Then right click and select menu item **Decompose Part of this Equation**. Then, in the "Type of Decomposition" form, select **RHS** (in the top box) to indicate that you are seeking to decompose the right hand side of this equation, select **Intelligent** (in the middle box) to indicate that you want AnalyzeGE to adopt the usual decomposition approach to this demand equation, select **First** (in the third box) to indicate that you want the decomposition toggle to come first in the ViewHAR file. and finally, click **Ok**. In the ViewHAR form which appears, make sure that the last 3 drop-down combo boxes read "Food", "SSA", "EU" respectively and first one reads "All IntDec1". You should see that the ams term has value zero, the qim term has value 0.71 and the ESUBM term has value 42.04. Thus the bulk of the increase in food imports from SSA into EU comes from the substitution term. You can identify the separate parts of this [use **Evaluate (selection or coeff/var at cursor)**] to see that the relevant substitution elasticity ESUBM("food") is 4.63 and that the price difference term pms("food","ssa","eu")-pim("food","EU") is equal to –9.07 (which indicates that the price of food from SSA into EU has fallen by over 9% relative to the average price of food imports into EU – you analysed this in section 3.2.1 above).

This analysis prompts the following two questions.

1. What would happen if the substitution elasticity ESUBM("food") were made larger or smaller? [Answer. The qxs("food","SSA","EU") result would be approximately proportional to the value of ESUBM("food") since the qim("food","EU") term is relatively small.]

2. Would the qxs("food","SSA","EU") result be larger or smaller if the share MSHRS("food","SSA","EU") were smaller or larger? [Answer. Changes in the MSHRS value will affect the relative price term, as the analysis in section 3.2.1 shows. If, on one extreme, MSHRS were 1, then the relative price term in the IMPORTDEMAND equation would be zero since then equation DPRICEIMP would say that pim("food","EU")=pms("food","SSA","EU"), that is, the full effect of the SSA price change would be reflected in the composite import price. Put another way – since there are no competing sources of imports, there is no scope for SSA to displace other suppliers, so this substitution term must be equal to zero. In the other direction, if the MSHRS value were even smaller than its current value of 0.04, the price difference term would be larger that it is now, so the imports of food from SSA into EU would increase by an even greater percent.]

3.3   How Increased Imports are Spread Across the EU Economy

In this section you will look into which agents in the EU use the increased imports of food.

Since imports are potentially used by all of the agents in the economy, a market clearing equation is required to add up the implications of changes in individual agents' demands for aggregate import requirements. This is the **MKTCLIMP** equation which says:

```
qim(i,r) = SUM(j,PROD_COMM, SHRIFM(i,j,r)*qfm(i,j,r)) +
            SHRIPM(i,r)*qpm(i,r) + SHRIGM(i,r)*qgm(i,r)
```

Demand by firms is given in the SUM(j,PROD_COMM, SHRIFM*qfm) term above, demand by private households is in the qpm term, and demand by government households is in the qgm term. The SHR*** items are shares. This is another very common type of equation in general equilibrium analysis and it is quite useful to see how AnalyseGE can assist in getting to the bottom of things in an efficient fashion.

You have seen in section 3.2.2 above that qim("food","EU") is 0.71. To see where these imports go in the EU, you can use AnalyseGE to decompose this equation. [Again choose Intelligent decomposition of the RHS, toggle first. In the ViewHAR form, arrange the drop-down combo boxes to read (from left to right) **All IntDec2, All TRAD_COMM, EU.**] You will see that the firms part of this 0.71 is approximately 0.26 (labelled SHRIFM in the ViewHAR form), the private households part is approximately 0.43 and the government part is approximately 0.02. It is often convenient to report these contributions as a percent of the total change. To do this here, you can use the "Shares" drop-down box in the top left hand corner of your ViewHAR form. This says "None" at present, indicating that you are viewing the actual value of the entry. Click on it and select "Col", which will show the column shares. You can then see that the private household's contribution to this total increase in EU demand for food is about 60%.

Now return to the TABLO file by selecting *Front | Bring TABmate to Front* from the menu in the ViewHAR form.

To see how the firms' part of 0.26 results from changing imports into the different firms, select (i.e. highlight with the mouse) the expression SHRIFM(i,j,r)*qfm(i,j,r) and Evaluate this for ("food",All_PROD_COMM,"EU")[34]; you will see that increased imports demanded by the food sector contribute approximately 0.15 of the total (labelled Food in the ViewHAR window), and that the mnfcs, svces and CGDS firm's contributions are approximately 0.04, 0.07 and 0.00 respectively. Using the column share feature of ViewHAR again, you can see that the food sector's share of the total is 59%. This is clearly the largest contribution to the increased food import demand by EU firms. It reflects the increased demand for imports used as an intermediate input in the production of the EU's own food outputs.

In summary, within a matter of minutes you are able to identify the key contributors to the change in import demand for food in the EU. The power of these tools increases as the dimensions of the problem increase. Imagine how helpful these tools would be if you were analysing a model with 30 regions and 30 sectors!

3.4   *Effect on the Food Sector in EU*

3.4.1   Demand for Food Imports by the EU Food Sector

Having identified the fact that the EU food sector is a very important contributor to overall import demand, you can further explore these changes by focusing on the appropriate equations in the model. Once again, there is a pair of equations describing a CES demand nest: ICOMPRICE (the price equation) and INDIMP (the CES demand equation). You can use AnalyseGE to look at these in much the same way as in section 3.2 above. For example, look at how qfm("food","food","EU"), the percentage change in the quantity of intermediate inputs of food into the EU food sector, is determined. Analysis will show that the sign of the expansion and substitution effects are in opposition to one another. To understand what happens to pfm("food","food","EU"), look at the equation which determines it.

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[34] That is, manipulate the drop-down combo boxes so that they read (from left to right) **food, All PROD_COMM, EU**.

3.4.2　Demand for Composite Food in the EU Food Sector

Having determined the change in import demand for food by the EU food sector, it remains to determine the change in demand for composite food qf("food","food","EU") – which is the expansion effect in the import demand equation. Here, there are once again two equations – the sector price (zero profit) equation and the derived demand equation INTDEMAND:

```
qf(i,j,r) = -af(i,j,r) + qo(j,r) - ao(j,r)
            - ESUBT(j)*[pf(i,j,r) - af(i,j,r) - ps(j,r) - ao(j,r)]
```

Inspection of the elements of the solution shows that the value for qf("food","food","EU") is the same as that for qo("food","EU"). Is this a coincidence? You can answer this by using AnalyseGE to look at the ESUBT values. You will see that they are all set to zero, which explains why these two values are the same (at least with these ESUBT values).[35]

3.5　Effect on SSA food sector

3.5.1　SSA food output

Of course one of the main variables of interest in this simulation is food output in SSA. How much does this tariff cut on EU imports of SSA food contribute to increased production? To investigate this point, search for the equation MKTCLTRD_NMRG which explains the change in output for each of the tradable commodities in this aggregation. Use AnalyseGE to evaluate the percentage change in SSA food output: qo("food", "SSA"). How much of this 4.6% increase is attributable to increased exports? To uncover this answer, perform an intelligent decomposition of the right hand side of this equation and use ViewHAR's share feature to verify that 82% of the increase in output is attributable to increased exports.

3.5.2　SSA domestic sales of food: A puzzle

Those readers with experience in trade policy analysis may be wondering at this point why domestic sales of SSA food went up. Indeed this is rather a puzzle, since the price of SSA food to SSA consumers of food has risen (verify this by searching for pm(i,r) and evaluating it). One would normally expect that a significant source of the increase in exports to EU would come from a reduction in domestic sales. Why do domestic purchases of SSA food rise? Use the skills you have learned up to this point to uncover the answer to this puzzle. (Hint: you will want to work with the market clearing equation for domestic sales: MKTCLDOM.)

3.6　Further Analysis

Of course, you can continue in this way to analyse the rest of the simulation results. For example, you may wish to investigate the effects of this preferential tariff cut on the third region, ROW, as it has been left out of this bilateral accord.

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[35] Thus, while the theory permits substitution among intermediate inputs, this possibility has been ruled out by the particular choice of the ESUBT parameters in this simulation.

4   Second Application: Analysis of technological change

Another type of shock that is quite common in GTAP-based analyses is a shock to the level of technology in a sector. There are a number of different types of technical change available in the standard GTAP model. In this application we will focus on a shock to the ao(i,r) variable, which represents Hicks-neutral input-augmenting technical change (neutral across all inputs). We draw on the first two experiments conducted by George Frisvold in Chapter 13 of the GTAP book (Frisvold, 1997). We will contrast the outcomes in these two experiments, using AnalyseGE to explain why they differ.

4.1   Technological change in ANZ crops

The first experiment involves a two percent shock to crops productivity in the Australia/New Zealand composite region: ao("crops", "ANZ") = 2%. To analyse this experiment, load the Solution file[36] **C2-09E1A.SL4**. Search over the variable ao and evaluate it to ascertain that this is indeed the shock being administered in this solution file.

4.1.1   Impact on ANZ crops sector

Begin by returning to the market clearing condition, MKTCLTRD, right-clicking on the variable qo and verifying that output of crops in ANZ rises by 2.32%. Next decompose the right hand side of this equation (using the same techniques used above) to verify that 90% of the increased output goes overseas.

Since the efficiency with which current inputs are used increases by 2%, some increase in total input usage is required in order to provide the additional 0.32% of output. This means that labor and capital used in ANZ crops, for example, must increase. Find the endowment market clearing condition, MKTCLENDWM, to further investigate this question. This equation states that the change in supply of primary factor endowments (left hand side) must equal the change in demand (right hand side). Evaluate qo on the left hand side to verify the primary factor endowments are fixed in this closure. This means that any increase in labor and capital usage must come from other sectors. To find out which sectors release primary factors, highlight the VFM*qfe term on the right hand side and evaluate it. Here you can see that most of the additional labor and capital come out of non-food manufacturing, but some comes out of livestock production. Food manufacturing and services actually increase usage of these factors.

4.1.2   Impact on ANZ livestock sector

We now turn to the impact of this technological change in crops on the ANZ livestock sector. If you return to ViewHAR and double-click on the qo header that was created previously, you will find that livestock production is decreasing (- 0.04%). For those with some familiarity with agriculture, this might seem odd. Livestock production typically involves the use of crops as an input and crops have become cheaper. Why then is livestock output falling?

A good way to get at the changes in cost structure of livestock production is to examine the associated zero profit equation, ZEROPROFITS, that requires any increase in costs to equal the change in price of that sector's output. Find this equation and decompose (intelligently) the right hand side. This will result in three terms: one relating the contribution of primary factors to total costs, one describing the same for intermediate inputs, and one relating to the

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[36] This is one of the Solution files supplied with the AnalyseGE demonstration package – see section 6. You should find it in the subdirectory GTAP2 of the directory in which you installed AnalyseGE.

(exogenous) slack variable's contribution – which may be ignored. The total change in costs is $1,234 million – and this is dominated by the increase in primary factor costs. In fact, variable input costs have actually fallen (relative to the numeraire price).

To verify that lower crop costs have indeed flowed through to the livestock sector, highlight the variable input portion of ZEROPROFITS[37] and evaluate it. You should find that the contribution of crops costs in the ANZ livestock sector is -$519. This is offset somewhat by higher costs for services and manufactures inputs, but overall, the cost of variable inputs to livestock production has declined.

What about primary factor costs? Highlighting this component of the right hand side of ZEROPROFITS[38] and evaluating this expression for (ALL ENDW_COMM, livestock, AustrNZ) shows that all primary factor costs have risen. However, the largest component of this increase is for land. This makes sense, since land is the factor for which crops and livestock production compete most directly. Land in this version of the GTAP data base is really agricultural land, and it is therefore only used in crops and livestock production. If crops expand their use of land, it must come from livestock production.

4.1.3   Disposition of ANZ livestock output

As a final step in this analysis, it is instructive to examine what happens to ANZ livestock output. To do this, return to the MKTCLTRD and either decompose the right hand side again, or locate the earlier intelligent decomposition in your HAR file. Here you can see that domestic sales have risen, while exports have fallen, and the latter dominates, so that total output falls. The reason for the decline in export sales may be quickly ascertained by searching for the next occurrence of pms(i,r,s) and evaluating this variable for i = livestock. From this you can see that the price of ANZ livestock products is rising relative to competing suppliers in virtually all markets. The underlying cause of this relative price change is a complementary shift of resources out of crops and into livestock in the non-ANZ regions.

What about the increase in domestic sales? Intelligent decomposition of MKTCLDOM, followed by evaluation of the term   SHRDFM(i,j,r)*qfd(i,j,r)   as j varies, shows that domestic sales of ANZ livestock products are driven by the increase in sales to the expanding food processing sector.

4.2   Technological change in NAM crops

The second experiment involves a two percent shock to crops productivity in the North American composite region: ao("crops", "NAM") = 2%. To analyse this experiment, load the file C2-09E1B.SL4. Search over the variable ao and click on it to ascertain that this is indeed the shock being administered in this solution file.

4.2.1   Impact on NAM crops sector

Once again, return to the market clearing condition, MKTCLTRD, right-click on the variable qo and verify that output of crops in NAM rises by 1.55%. Next decompose the right hand side of this equation (using the same techniques used above) to verify that now only 72% of of the increased output goes overseas. Why is this less than the 90% for ANZ in the previous example?

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[37] This is the expression   VFA(i,j,r)*[pf(i,j,r) - af(i,j,r)]. Select (or highlight) this with your mouse.
[38] This is the expression   VFA(i,j,r)*[pfe(i,j,r) - afe(i,j,r) – ava(j,r)].

Now the efficiency with which current inputs are used increases more than the amount of input usage required to meet the 1.55% increase in output, so that you would expect resources to leave the crops sector. Verify this fact by going to the endowment market clearing condition, MKTCLENDWM, highlighting and evaluating the right hand side term relating to sectoral usage of mobile endowments. Now (in contrast to the ANZ case in section 4.1 above)the livestock sector is absorbing labor and capital from crops (and land as well – although you can't see that from this equation, since land is a sluggish endowment).

4.2.2 Impact on NAM livestock sector

The qo header that you generated a moment ago can be recalled and this shows that livestock output now rises (as opposed to falling in the ANZ case). Returning to the zero profit equation, ZEROPROFITS, you can see that both the primary factor contribution and the intermediate input contribution to costs are now negative. If you explore the cost share structure of NAM livestock, you will also see that it is much more heavily reliant on crops than ANZ livestock, which is another reason for output to expand in the NAM case when crops productivity increases.

4.2.3 Disposition of NAM livestock output

Finally we turn again to the disposition of livestock output. Returning to MKTCLTRD and decomposing the right hand side, you can see that domestic sales and exports both rise now. The reason for the increase in export sales may be found, as before, by searching for the next occurrence of pms(i,r,s) and evaluating this variable for I = livestock. From this you can see that the price of NAM livestock products falls relative to competing suppliers in virtually all markets.

4.3 Summary and further investigations

In summary, AnalyseGE greatly facilitates the analysis of these two experiments, permitting us to uncover the reasons behind the differential impact of crops productivity growth on livestock production in two different regions of the world economy.[39]

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[39] The reader who is interested in further understanding the fundamental reasons for the differential impact on input use in the two crops sectors might be interested in investigating the general equilibrium demand elasticities underlying this model. A detailed discussion of GE demand elasticities in general – and this application in particular – is available in the help file for RunGTAP. That software can also be used to generate and decompose GE demand elasticities for any implementation of the standard GTAP model.

5 Other Features of AnalyseGE

Although we have illustrated AnalyseGE with the GTAP model, the software is completely general-purpose. It can be used to assist with the analysis of any simulation carried out using Release 7.0 (or later) of GEMPACK.

AnalyseGE is fully documented via the Help file which accompanies it. You can find details there about several features we have introduced only briefly in this paper.

The main function of AnalyseGE is to assist with calculations involving data and/or simulation results. The main way of doing such calculations is via the TABmate form, as has been illustrated in the sections above.

Sometimes you may want to carry out calculations which cannot be initiated from the TABmate form, and sometimes the calculations initiated from the TABmate form turn out to be not quite what you want. In such cases it is possible to enter the formulas you want in the memo on the AnalyseGE form. The syntax is very similar to that in TABLO Input files (though AnalyseGE often allows you to omit quantifiers). Full details of this way of initiating calculations can be found in the Help file supplied with AnalyseGE. [Note that when AnalyseGE carries out a calculation initiated from the TABmate form, the corresponding formulas etc are always visible in the memo on the AnalyseGE form after the calculation has been completed. You can look here to check exactly what was calculated, and also to get a good idea as to the sorts of formulas etc that can be entered into that memo.]

The **View** menu on the AnalyseGE form is often useful. This lets you view

- the Command file used for the simulation. This contains the full instructions for the simulation, including the closure and shocks.
- the Sets, Subsets, Variables and Coefficients in the model.
- the Stored-input file used to condense the model when running TABLO (if condensation was carried out).

In fact Release 7.0 of GEMPACK stores the Command file, the TABLO file (which you see in the TABmate window) and the Stored-input file used to run TABLO on the Solution file. AnalyseGE recovers them from there.

When a TABLO-generated program or GEMSIM from Release 7.0 of GEMPACK carry out a simulation, they create a so-called **SLC file** as well as the usual Solution file. This SLC (Solution Coefficient values file) contains the pre-simulation values of all Coefficients from the TABLO Input file. In particular this contains essentially a copy of the pre-simulation data read (as well as the values of Coefficients whose values are obtained from this pre-simulation data via formulas).

Together the Solution and SLC files provide a very strong audit trail for the simulation. They contain the TABLO Input file for the model, the Command file, the Stored-input file used to run TABLO, and all the pre-simulation data.

6 Installing AnalyseGE on Your Computer

The AnalyseGE files (including the Solution files for the two applications described in this paper) can be downloaded from the Web from address

http://www.monash.edu.au/policy/gpange.htm

Follow the instructions there to install AnalyseGE on your computer.

Note that you will not be able to use AnalyseGE to assist in the analysis of your own applications unless you have Release 7.0 (or later) of GEMPACK installed, since AnalyseGE can only be used with Solution files produced by this release (or later releases) of GEMPACK.

7 Conclusion

In this paper we have introduced the capabilities of AnalyseGE.

You can use AnalyseGE to calculate any formula involving simulation results, pre-simulation data and Coefficients of the model. The main way of initiating such calculations is via the TABmate form, however you can also use the memo on the AnalyseGE form (see section 5).

As outlined in section 5, the Solution and SLC files form a strong audit trail for any simulation.

We hope that this software is able to assist modellers analyse their simulation results. For experienced modellers, we hope that it will make them more efficient in their analysis of GE simulations – thereby enabling them to delve more deeply into the mechanisms underlying the results. For non-modellers, we hope that, by making such analysis easy and rewarding, economists will be increasingly drawn back to the fundamental equations of the model, thereby discouraging "confabulation" and encouraging sound analysis.

8 Appendix 1 : Why Linearized Equations are Not Satisfied Exactly

As you have seen in several places in the main text, the linearized equations of the model are not satisfied exactly when you look at them using AnalyseGE. We explain why in detail in this appendix. This is a more technical section and some readers may prefer to skip it.

8.1 Linearization of a Product

Some equations are obtained by linearizing a levels equation which is a product. An example is the equation **MKTPRICES** considered in section 1.1. In the levels this says that the market price PMS_L(i,r,s) of commodity i from region r imported into region s is the product of the cif price PCIF_L(i,r,s) and the powers of the import tariff TMS_L(i,r,s).[40] The levels equation is thus

```
PMS_L(i,r,s) = PCIF_L(i,r,s) * TMS_L(i,r,s)        (1LEV)
```

To simplify matters, we focus on a specific triple – say food from SSA into EU – and omit the (i,r,s) in each case. Suppose that initially the cif price PCIF_L is 1 and that the power of the import tariff TMS_L is 1.5 (that is, a 50 percent *ad valorem* import tariff). Then the pre-simulation value of PMS_L is 1.5. Now suppose that in the simulation there is a reduction in TMS_L by 10% and that the value of PCIF_L also falls by 10%. That is, TMS_L is reduced from 1.5 to 1.35 and PCIF_L falls from 1 to 0.9. Then, clearly the post-simulation value of PMS_L is 0.9*1.35=1.215 so that PMS_L falls from 1.5 to 1.215 which is a reduction of 19%.

The linearized equation is

```
pms(i,r,s) = pcif(i,r,s) + tms(i,r,s)             (1LIN)
```

We interpret the variables in this equation as the percentage changes in the corresponding levels variables. If you substitute the simulation results into this linearized equation (as happens when you use AnalyseGE), you will see that the left-hand side equals –19 (the exact simulation result for PMS_L) while the right-hand side equals –10 + -10 = -20. This confirms that the linearized equation is not satisfied exactly by the simulation results.

Indeed, you would not want it to be satisfied exactly. If variables pms, pcif and tms are the percentage changes in variables PMS_L, PCIF_L and TMS_L connected via equation (1LEV) above, it is easy to see that the exact equation connecting them is

```
pms = pcif + tms + [pcif*tms/100]          (1EXACT)
```

You can check this by substituting pcif=tms=-10 into the right-hand side, and you will see that the right-hand side does evaluate to –19 as expected.

You can see that the linearized equation in the TABLO Input file (the equation (1LIN) above) is only an approximation to the exact equation (1EXACT) because the cross-product term [pcif*tms/100] is omitted.

Of course, the linearized equation (1LIN) will be satisfied approximately by the accurate simulation results provided that the percentage changes are not too large.

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[40] In the explanation here, we omit the term tm(i,s) to simplify things.

8.2 Shares Vary

Other equations in the TABLO Input file contain shares (or other Coefficients). Typically the values of these shares or coefficients change between the pre-simulation data base and the post-simulation one. An example is the equation **DPRICEIMP** considered in section 3.2.1. This equation is

```
pim(i,s) = SUM(k,REG, MSHRS(i,k,s) * pms(i,k,s) ) ;
```

Here suppose (as in section 3.2.1) that we are interested in this for i=food and s=EU. The relevant shares are MSHRS(food,k,EU) for the 3 different values of k. The pre-simulation values of these shares MSHRS(food,k,EU) are

0.04 (k=SSA), 0.71 (k=EU) and 0.25 (k=ROW)

(as you can see using AnalyseGE). The post-simulation values are

0.06 (k=SSA), 0.70 (k=EU) and 0.24 (k=ROW) [41]

In the analysis in section 3.2.1 above when i=food and s=EU, the left-hand side of the linear equation above is –0.58 while the terms on the right-hand side add to –0.48. There are two reasons for this difference. Firstly the shares MSHRS vary across the simulation. Secondly, (as in section 8.1 above), the linearized equation is only an approximate version of the underlying levels equation for the price part of this CES nest.

Note that the linearized equation would not be satisfied exactly if we used post-simulation values for MSHRS or even an average of pre- and post-simulation values (though the discrepancy would be less in the latter case).

8.3 General Comments

You should not expect the linearized equations to be satisfied exactly when looked at in AnalyseGE. Normally you can expect them to be satisfied sufficiently well that the values obtained via AnalyseGE are useful in explaining simulation results.

If you are puzzled as to how GEMPACK is able to obtain arbitrarily accurate solutions of the underlying levels equations of the model even though it seems only to use the linearized equations, the answer is partly that the update statements in the TABLO Input file ensure that each time a small part of the shock is applied, the data values and shares are recalculated. A more detailed intuitive explanation can be found in section 2.13.3 of GEMPACK document number GPD-1 [see Harrison and Pearson (2002)]. A more technical and complete explanation can be found in Pearson (1991).

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[41] One way of finding these values is to run a simulation starting from the post-simulation data base from the simulation being analysed in section 3, and then use AnalyseGE to analyse this – then the shares shown will be as in the post-simulation data base from the first simulation.

9   References

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