Model Exercises

Introduction

The objective of these eight model exercises, and an additional challenge exercise, is to provide you with step-by-step guidance in building a model, designing experiments, identifying relevant results, and interpreting findings.

The exercises are intended to:

- Engage your interest by showing the breadth of real world problems that can be analyzed using a CGE model.
- Illustrate how to use economic theory to make predictions about and to interpret model results.
- Demonstrate how the design of model experiments is grounded in economic theory and background research.
- Introduce a broad sampling of methodological tools, including how to change elasticities and model closure, decompose shocks into subtotals, and run sensitivity analyses of assumptions about elasticity parameter values and shock sizes.

The case studies are suitable for use with many types of CGE models. However, the detailed instructions provided in the model exercises are designed for use with the Global Trade Analysis Project (GTAP) CGE model. The model, developed by Thomas Hertel and colleagues at Purdue University, is documented in Hertel and Tsigas, 1997. Its friendly, menu-driven interface, RunGTAP, was developed by Mark Horridge (2001) and is ideal for use by novice modelers.

Model exercises 1–3 show you how to create a small, three-sector, three-factor database for the United States and an aggregated, rest-of-world region from the GTAP global database (Table 1 ME introduction 1). The instructions also guide you in setting up, running, and learning about the GTAP CGE model. You should complete these three exercises sequentially before doing the subsequent case studies. You can also use the model developed in these exercises to replicate the modeling results reported throughout the textbook chapters.

Table ME Introduction 1. *Skill Development in Model Exercises*

Exercise	Case Study	Economic Concepts	Modeling Skill
1. Set up the GTAP model and database			Download GTAP model, develop a database and SAM, run the model
2. Explore the GTAP model and database			Locate elements of model: sets, parameters, variables, equations, closure, and market-clearing constraints
3. Run the GTAP model			Define and run experiments, change elasticities and closure, read results, use GTAP utilities for welfare decomposition,and systematic sensitivity analysis
4. Soaring food prices and the U.S. economy	Trostle (2008), Sachs (2008), Cline (2008), Collier (2008)	Comparison of utility functions. Armington import demand, small country assumption	Change income and substitution demand elasticities, small country (fixed world price) closure
5. Food fight: Agricultural production subsidies	Samuelson (2005)	Production function, production subsidies	Use GTAP SUBTOTAL utility, change factor substitution elasticity
6. How immigration can raise wages	Borjas (2004), Ottaviano and Peri (2006)	Factors as substitutes and complements, factor endowment changes and factor prices	Change factor endowments and factor substitution elasticity
7. The Doha Development Agenda	Anderson and Martin (2005)	Input, output and export subsidies, import tariffs, welfare analysis	Use GTAP SUBTOTAL and welfare decomposition utilities, compare models

Exercise	Case Study	Economic Concepts	Modeling Skill
8. The marginal welfare burden of the U.S. tax system	Ballard, Shoven and Whalley (1985)	Taxation, tax burdens, welfare analysis	Use GTAP welfare decomposition and systematic sensitivity analysis utilities
9. Challenge exercise: Successful Quitters: the Economic Effects of Growing Anti-Smoking Attitudes	Goel and Nelson, 2004.	Utility functions, changes in consumer preferences, parameter uncertainty	Update model with macroeconomic projections, use GTAP systematic sensitivity analysis utility

Model Exercises 4–8 provide case studies that complement and reinforce the concepts learned in the related chapters of the textbook. You can do all, or any one, of these exercises, and in any sequence. Model Exercise 9 presents more challenging techniques for the advanced student. Model Exercises 4-9 are ideal for use as small, collaborative group projects. Each exercise poses questions about model results that can serve as a starting point for your exploration and study of your findings.

An important caveat about the model exercises is that they are only a teaching tool. Although the exercises introduce real-life problems and the practical modeling skills used in their analysis, the results from your small-dimensioned, toy CGE model should not be relied upon as realistic.

Model Exercise 1: Set Up the GTAP Model and Database

Concepts: Download GTAP model, develop a model database, create a SAM, create model version, run GTAP model

In this exercise, you will learn how to (1) build a CGE model database and (2) set up and run a version of the GTAP model to use with your database.[1] In the first step, you will download the GTAP global database aggregator from the GTAP Web site. You will learn how to use the database aggregator to create a two-region, three-sector and three-factor database that we use for examples throughout the book and in the model exercises. The two regions are the United States (USA) and the rest of the world (ROW); the three sectors are agriculture, manufacturing, and services; and the three factors are land, labor, and capital. We use the GTAP 7.0 database, released 21 November 2008. You may carry out the model exercises with versions 5 and higher of the GTAP database but model results will differ from those reported in the answer key.

In the second step, you will download the RunGTAP model and learn how to create a "version" of the model to run with your 3x3 database. At the end of this exercise, your CGE model and database will be ready to use for analysis or to replicate modeling examples in Chapters 1–8.

A. Create a Folder on Your Computer for Your Project

Ccreate a folder on your computer in which you will save your database and all of the other files that you will create for your research project. Name the directory "MyLastName" or something else that is easy to remember.

B. Download the Database Aggregator and Create a Model Database

The GTAP model can be used interchangeably with any aggregation of the GTAP database. You will create a three-sector, three-factor aggregation that describes the United States and an aggregated rest-of-world region. We refer to it as the U.S. 3x3 database throughout this book. You can follow these same steps to create a database for your individual research project. Instead of the United States and rest of world, you may choose to study different aggregations of countries, industries, and factors of production. We encourage you to limit yourself to no more than ten industries and four factors of production. (Without a GTAP license, you are restricted to three

[1] For students with some experience in GEMPACK, Pearson and Horridge (2003) provide a detailed introduction to the GEMPACK software and its use in the GTAP model. Also, see Horridge (2008a and 2008b) on use of the GTAP aggregation utility.

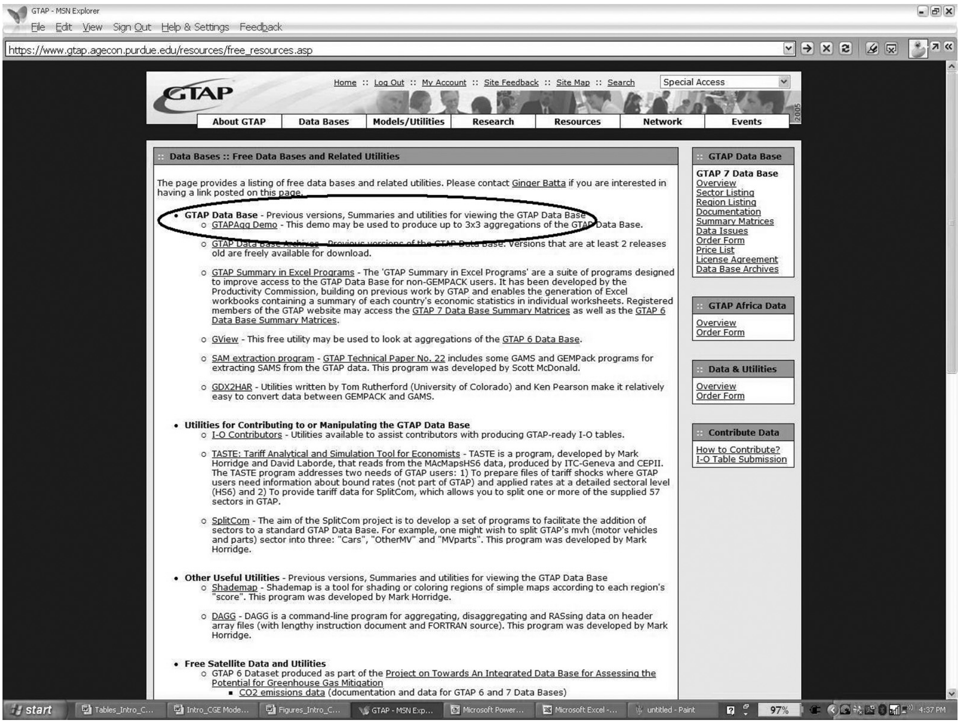


Figure ME 1.1. Download GTAP-Agg demo

countries and three sectors.) Otherwise, it becomes difficult to distill key results and major findings, especially as a beginning modeler.

The instructions below are consistent with the GTAP website as of October 2010. You may need to adapt these instructions if the GTAP website changes over time.

1. go to www.GTAP.org
2. Become a member of GTAP. Select “My Account” from the top menu bar and register as a new member. If you are a member already, log in.
3. From the main menu:
   > Select Databases
   > Select Free Databases from the drop down menu
   > Select GTAP-Agg Demo (see Figure ME 1.1).
   > Click on GTAPAgg7 Demo, from the “Attachments” section at the bottom of the page.
4. Download the GTAP-Agg demo file and select “Unzip and Install.” Then select “set-up” program. It will prompt you to install the program to your hard disk in directory “C:/GTPAg7.” You may instead specify any drive in which you prefer to install the program. (If this installation process is not an option on your computer, save the zip file to your temp directory. You can continue the set-up process from there, first by clicking on the zipped file, labeled “4144,” and then by clicking on the “set-up” computer icon within it.)

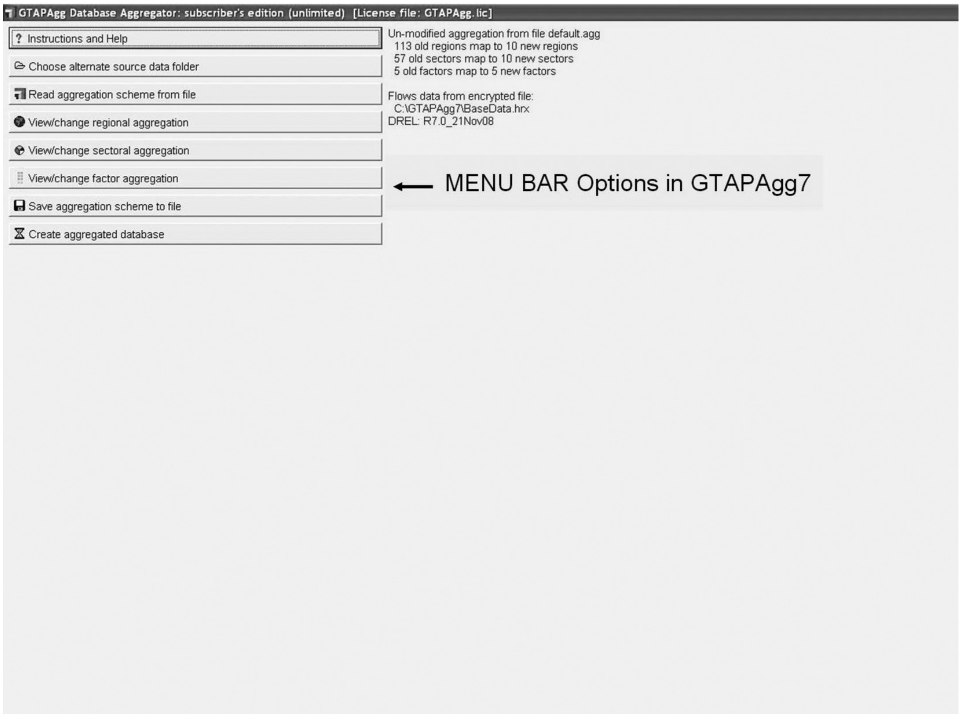


Figure ME 1.2. GTAPAgg7 menu bar options

5. As of this writing (November 2010) a patch to the GTAPAgg7 program is required to enable it to generate a Social Accounting Matrix, the format used to organize and display the databases used in CGE models. Download the patch from the following Web site, and *follow the installation directions for the patch*:
   > go to http://www.monash.edu.au/policy/aggpatch.htm
   > Open the GTAPAgg7 program. (Either click on GTAPAgg7 icon on the desktop or go to "Start," and select "All Programs," then select "GTAPAgg7."). The GTAPAgg7 program will open and display the menu bar options shown in Figure ME 1.2.
   > Check that you have updated the GTAPAgg7 program by clicking on the globe in the lower right corner. The version should be 7.10 or higher.
6. Define the country aggregation.
   > From the menu bar options, select "View/change regional aggregation"
   > In the table at the bottom of the page (shown in Figure ME 1.3), define two regions by right-clicking on rows and deleting all but two.
   > In the left column of the table, "New region code," re-label the rows "USA" and "ROW"
   > In the right column of the table, "New region description," enter "United States" and "Rest of World" to match the new region codes
7. Map all countries into a two-region aggregation
   > Go the mapping table in the upper right quadrant of the page.

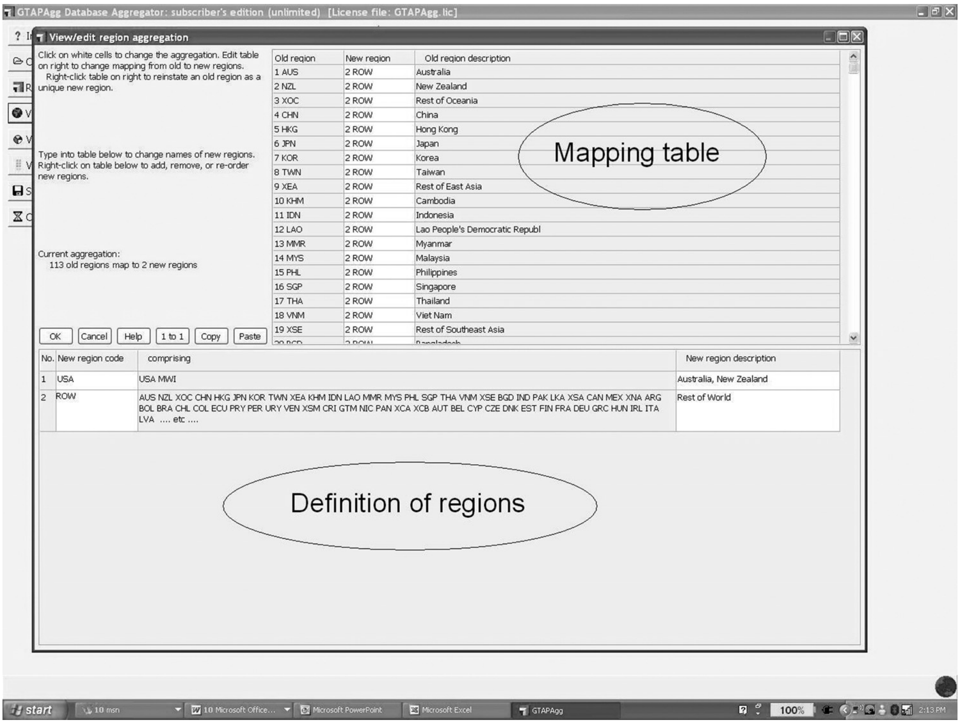


Figure ME 1.3. Mapping regions in GTAPAgg7

> Click on the first row (Australia), and the center column (New region) and pull down the menu, which should list "USA" and "ROW."

> Map each country in the mapping table to one of the two regions. When you are finished, only "USA" should occupy the "comprising" column in the table at the bottom of the page for the newly defined "USA" region. All other regions should be mapped to "ROW."

> Click OK (this saves your regional aggregation)

8. Define the sector aggregation.

   > From the menu bar, select "View/change sectoral aggregation." This opens a mapping page similar to that used to create the regional aggregation (shown in Figure ME 1.4).

   > In the table at the bottom of the page, right-click to remove all but three sector rows.

   > In the left column of the table, "New sector code," re-label the rows "AGR," "MFG," and "SER"

   > In the right column, "New sector descriptions," describe these sectors as Agriculture Natural Resources, Manufacturing, and Services.

9. Map sectors to a three-sector aggregation

   > In the mapping table in the upper right quadrant of the page, click on the first row (paddy rice) and the center column (New sector) and pull down the menu, which should list "AGR," "MFG," and "SER."

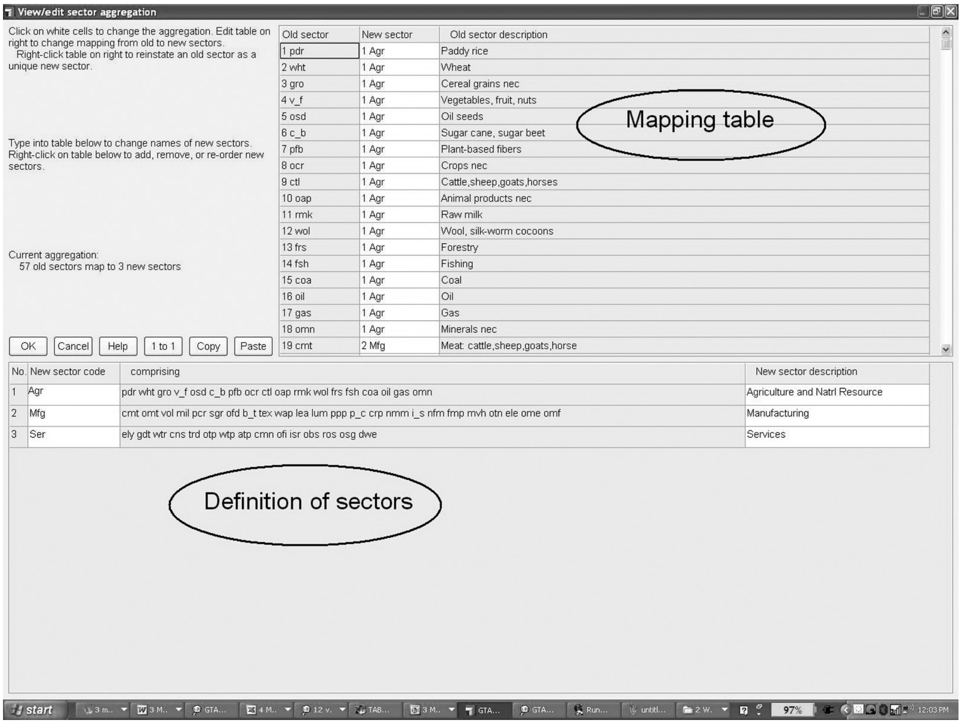


Figure ME 1.4. Mapping sectors in GTAPAgg7

> Map sectors 1–18 into AGR; sectors 19–42 into MFG; sectors 43–57 into SER.
> OK (this saves your sector definitions)

10. Define the factor aggregation
  > From the menu bar, select "View/change factor aggregation." This opens a mapping page similar to that used to create the regional aggregation (shown in Figure ME 1.5).
  > In the table at the bottom of the page, right-click to remove all but three factor rows.
  > In the left column, type "Land," "Labor," and "Capital," putting one factor in each row .
  > In the column labeled "Comprising," type "Land," "Labor," and "Capital" in the appropriate row.
11. Define factor mobility assumptions
  > The column labeled "ETRAE or mobile" describes the model's factor mobility assumptions. We study factor mobility assumptions in detail in Chapter 6. For now, simply change all factor mobility assumptions in this column to "mobile."
12. Map factors into three-factor aggregation
  > In the mapping table in the upper right quadrant, click on the center column, "New factor," and pull down the mapping menu.
  > Map: land to LAND; skilled and unskilled labor to LABOR; and capital and natural resources to CAPITAL.
  > OK

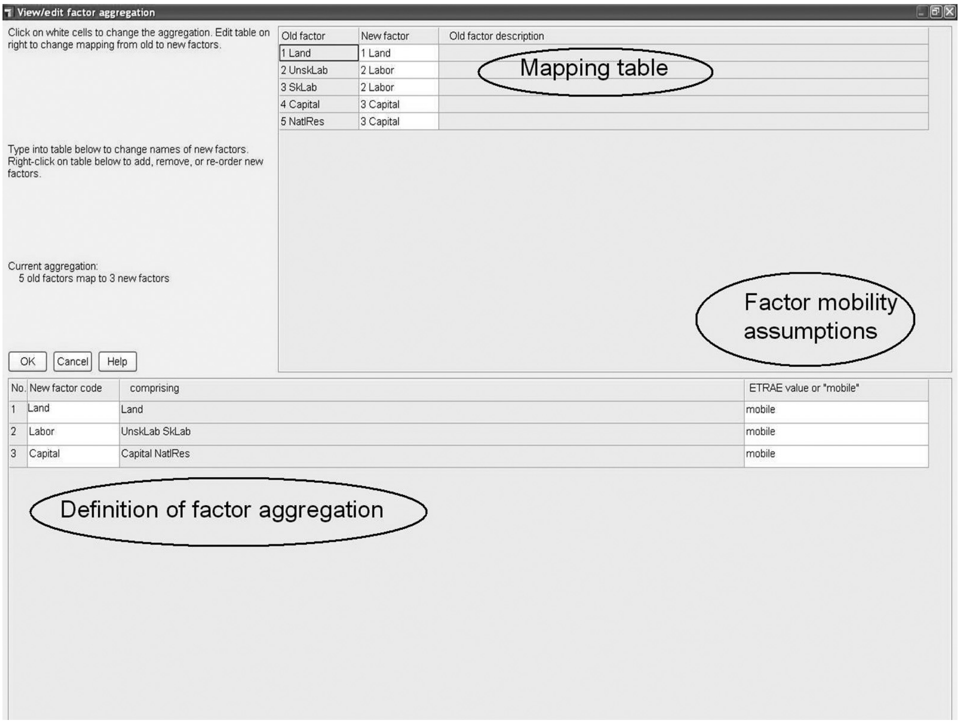
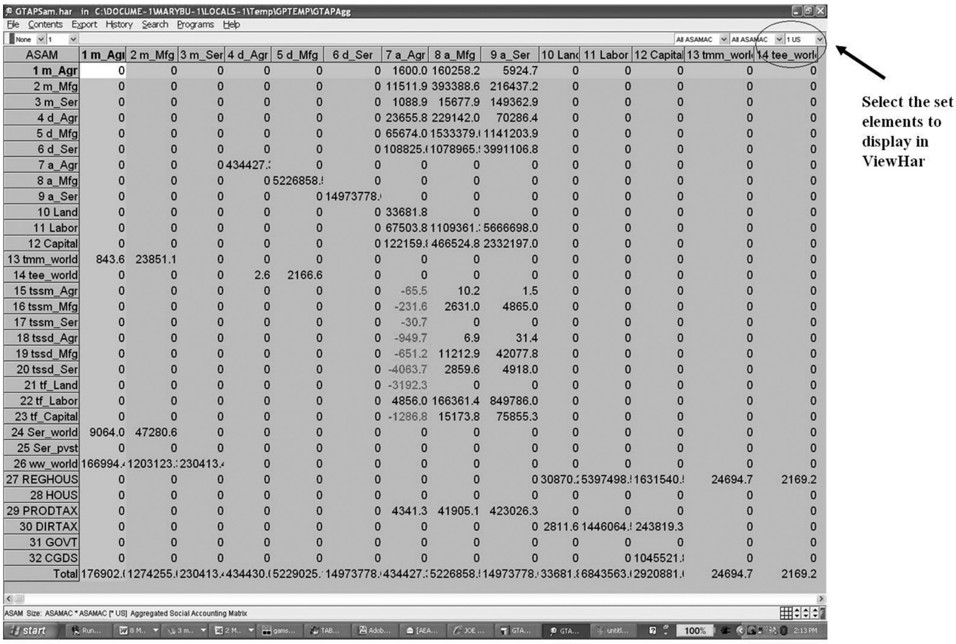


Figure ME 1.5. Mapping factors in GTAPAgg7

13. Save your data aggregation file
    > From the menu bar, select "Save aggregation scheme to file." (GTAP provides a default name, "gtp3_2," which you can change to something more descriptive, like US3x3.
    > Save this aggregation file in the folder that you created for your research project.
14. Create the aggregated database.
    > From the menu bar, select "Create aggregated database." This creates a zip file with the aggregated database. Give it the same name as your aggregation scheme (e.g., US3x3.zip), and save it in your project folder.
    Your database is now saved in Header Array (HAR) files that are ready to use in your CGE model.
15. Create a Social Accounting Matrix (SAM) in EXCEL
    > From the menu bar, select "View Output files."
    > Select GTAPSAM.har (this opens a list of HAR, or header array, files)
    > Click on ASAM – Aggregated Social Accounting Matrix. This will open a file in ViewHar, the software that is used to view HAR files.
16. Display the U.S. SAM
    A HAR file often contains data of more than two dimensions. To display the data of interest to you, select the dimensions, or elements, of the database in the upper right corner of the file (shown in Figure ME 1.6). To display all SAM accounts for the United States, select these dimensions:
    ALL ASAMAC, ALL ASAMAC, USA



ASAM	1 m_Agı	2 m_Mfg	3 m_Ser	4 d_Agr	5 d_Mfg	6 d_Ser	7 a_Agr	8 a_Mfg	9 a_Ser	10 Lan	11 Labor	12 Capital	13 tmm_worl	14 tee_worl
1 m_Agr	0	0	0	0	0	0	1600.0	160258.2	5924.7	0	0	0	0	0
2 m_Mfg	0	0	0	0	0	0	11511.9	393388.6	216437.2	0	0	0	0	0
3 m_Ser	0	0	0	0	0	0	1088.9	15677.9	149362.9	0	0	0	0	0
4 d_Agr	0	0	0	0	0	0	23655.8	229142.0	70286.4	0	0	0	0	0
5 d_Mfg	0	0	0	0	0	0	65674.0	1533379.	1141203.9	0	0	0	0	0
6 d_Ser	0	0	0	0	0	0	108825.	1078965.	3991106.8	0	0	0	0	0
7 a_Agr	0	0	0	434427.	0	0	0	0	0	0	0	0	0	0
8 a_Mfg	0	0	0	0	5226858.	0	0	0	0	0	0	0	0	0
9 a_Ser	0	0	0	0	0	14973778.	0	0	0	0	0	0	0	0
10 Land	0	0	0	0	0	0	33681.8	0	0	0	0	0	0	0
11 Labor	0	0	0	0	0	0	67503.8	1109361.	5666698.0	0	0	0	0	0
12 Capital	0	0	0	0	0	0	122159.	466524.8	2332197.0	0	0	0	0	0
13 tmm_world	843.6	23851.1	0	0	0	0	0	0	0	0	0	0	0	0
14 tee_world	0	0	0	2.6	2166.6	0	0	0	0	0	0	0	0	0
15 tssm_Agr	0	0	0	0	0	0	-65.5	10.2	1.5	0	0	0	0	0
16 tssm_Mfg	0	0	0	0	0	0	-231.6	2631.0	4865.0	0	0	0	0	0
17 tssm_Ser	0	0	0	0	0	0	-30.7	0	0	0	0	0	0	0
18 tssd_Agr	0	0	0	0	0	0	-949.7	6.9	31.4	0	0	0	0	0
19 tssd_Mfg	0	0	0	0	0	0	-651.2	11212.9	42077.8	0	0	0	0	0
20 tssd_Ser	0	0	0	0	0	0	-4063.7	2859.6	4918.0	0	0	0	0	0
21 tf_Land	0	0	0	0	0	0	-3192.3	0	0	0	0	0	0	0
22 tf_Labor	0	0	0	0	0	0	4856.0	166361.4	849786.0	0	0	0	0	0
23 tf_Capital	0	0	0	0	0	0	-1286.8	15173.8	75855.3	0	0	0	0	0
24 Ser_world	9064.0	47280.6	0	0	0	0	0	0	0	0	0	0	0	0
25 Ser_pvst	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26 ww_world	166994.	1203123.	230413.	0	0	0	0	0	0	0	0	0	0	0
27 REGHOUS	0	0	0	0	0	0	0	0	0	30870.	5397498.	1631540.	24694.7	2169.2
28 HOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29 PRODTAX	0	0	0	0	0	0	4341.3	41905.1	423026.3	0	0	0	0	0
30 DIRTAX	0	0	0	0	0	0	0	0	0	2811.6	1446064.	243819.3	0	0
31 GOVT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32 CGDS	0	0	0	0	0	0	0	0	0	0	0	1045521.	0	0
Total	176902.	1274255.	230413.	434430.	5229025.	14973778.	434427.	5226858.	14973778.	33681.	6843563.	2920881.	24694.7	2169.2

Figure ME 1.6. The U.S. Social Accounting Matrix in ViewHar

17. Export the U.S. SAM database to Excel
    > From the menu bar on the ViewHar page, select "Export"
    > Select "Copy Screen to Clipboard" from dropdown menu
    > Open Excel
    > Paste SAM into an Excel file and save it as US3x3.xls.
    > Verify that your SAM's column sums match those displayed in Figure ME 1.6. If they do not, reopen your aggregation file and check your definitions of regions, sectors, and factors, for errors. Correct them and re-create the aggregated database.

C. Download the GTAP Model

These directions for downloading, unzipping, and installing the GTAP model are quite general. Your computer and browser may present a slightly different set of choices for how to do this. The important thing is that you download the model, unzip it and locate the SETUP.exe file, and run the installation program. The installation will create a directory on your hard drive, RunGTAP5, in which the model will be placed.

1. Go to www.GTAP.org
2. From the main menu bar:
   > Select Models/Utilities
   > Select RunGTAP, from the Models/Utilities dropdown menu
   > Select Download RunGTAP, from the RunGTAP downloads section.

Figure ME 1.7. GTAP model

3. Download the file and select “Unzip and Install.” Then select “Set-up” and the program will prompt you to install the program to your hard disk. The default directory is C, but you may choose to install it in a different directory. (Another option is to download and save the file to your temp directory and install it from there, first by clicking on the zipped RunGTAP file and then by clicking on the “set-up” computer icon inside it.)

D. Create a Version of the GTAP Model for the US3x3 Database

The GTAP model is expressed in general functional notation so that it can be used with any database. In this exercise, you will create a “version” of the GTAP model that uses the U.S. 3x3 database. The model version will be called, “US3x3.” You can follow these same steps to create a version of the GTAP model that works with any database that you choose to aggregate.

1. Open the RunGTAP model by clicking on the Windows icon for RunGTAP or open it from your start menu. The title page includes a menu bar at the top, and page tabs below the menu bar (Figure ME 1.7). The first time you open it, there may be a warning that an SLI file is missing or obsolete. If so, select “OK.”
2. Create a U.S. 3x3 version of your model. In RunGTAP:
   > Select “Version” from the menu bar.

> Select "New" from the dropdown menu
> Next
> New Aggregation and NAME it: US3x3
> Next
> Click on "Locate the Zip archive" (the bottom "locate button")
> Select the US3x3 zip file in the folder that you created for your research project, and click on "Open"
> Next
> Finish
> OK

There is now a folder with the name of your version (i.e. US3x3) saved in the RunGTAP5 directory. GTAP software automatically runs a test of the model version using your data. When this is completed, your U.S. 3x3 model is calibrated and ready to use for experiments.

3. Describe the version of your model
> From the menu bar in the RunGTAP model, select "Tools"
> Select "Options"
> Check the "Developer mode" box
> OK
> Select Version from the page tabs (not from the menu bar above)
> Delete all the text on this page and write your own brief description of your USA 3x3 model; for example, "USA 3x3 model has two regions (U.S. and Rest of World), three factors (Land, Labor, and Capital), and three sectors (Agriculture, Manufacturing, and Services).
> From the menu bar, select Developer
> Select "Save Version.txt" from the dropdown menu
> OK
> From the menu bar, select Tools
> From the dropdown menu, select "Options"
> Uncheck the "Developer mode" box
> Select "OK"

When you open the GTAP model, it always opens the last version that you worked on. If you want to work with a different version, or if you want to change versions as you are working, select "Version" from the menu bar (at the top of the page), and you will find a list of model versions, including the U.S. 3x3 and any other versions that you have created. Select the version that you want to open.

E. Change to Uncondensed Version of the Model

In this course, we will use the "uncondensed" version of the GTAP model, which includes more tax and productivity parameters than the default, condensed version. To switch to the uncondensed version:

1. Change the model version.
   > Select "Version" from the menu bar
   > Select "Modules" from the dropdown menu
   > In the Main model row, click on GTAP in the center (Tab file) column
   > Select GTAPU.TAB from the menu box
   > Click on OK
   > OK
   > OK
2. Run a test simulation:
   > Select "Tools" from the menu bar
   > Run test simulation from the dropdown menu
   > Continue to select OK if there are bad closure warnings, even if there are several.

The GTAP program will now use the uncondensed GTAP model for any model version that you open.

Model Exercise 2: Explore the GTAP Model and Database

Concepts: Locate elements of model – sets, parameters, variables, equations, closure and market-clearing constraints.

The objective of this model exercise is to give you an orientation to the main components of the CGE model and its database. You will learn how to open and search the CGE model's program code, and you will locate and identify your model's sets, parameters, variables, closure, and market clearing constraints.

A. Open the Version of the GTAP Model with U.S. 3x3 Database

1. Open "RunGTAP"
2. On the menu bar, choose "Version"
   > Change
   > Select US3x3
   > OK

B. Explore the Sets in the Database.

1. Open the sets file
   > On the menu bar, select "View"
   > From the dropdown menu, select "Sets"

This opens a HAR file that lists all sets in the model (Figure ME 2.1).
Identify the regions in the model database

> Double click on Set REG (in row 2).
> Write the elements of REG (regions in model):

____

3. Identify the sectors in the model (they are called traded commodities)
   > Click anywhere in the matrix to return to the previous menu
   > Double click on Set TRADE_COMM (in row 3).
   > Write the elements of TRAD_COMM (traded commodities):

____

4. Identify the factors in the model

> Click anywhere in the matrix to return to the previous menu.
> Double click on Set ENDW_COMM (in row 4).
> Write the elements of ENDW_COMM (factors of production):

____

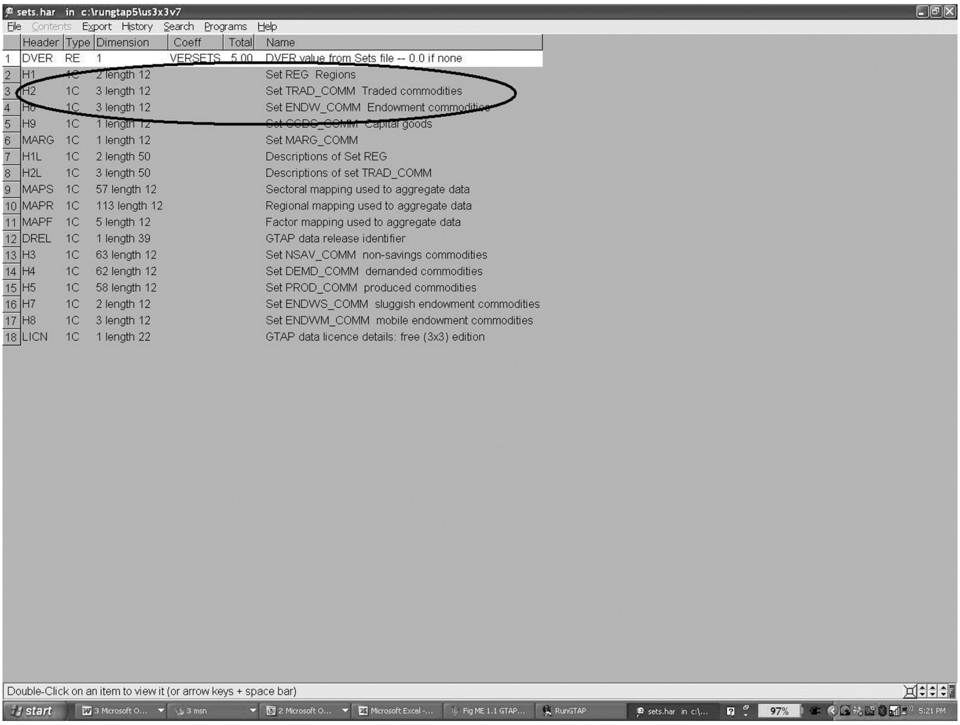


Figure ME 2.1. View set elements

> Close the sets.har file by clinking on the red x in the upper right corner of the HAR file.

C. Explore Table Dimensions of a HAR File

Tables have only two dimensions, rows and columns, yet many variables in the CGE model have more than two dimensions. For example, in the GTAP model, parameter rTMS(TRAD_COMM, s, r) is the import tariff rate on traded goods imported by country *r* from country *s*. The parameter has three dimensions: It is defined for the set of traded goods (TRAD_COMM); the set of source countries, *s;* and the set of destination countries, *r*. To explore variables like this one, you will need to learn how to view variables and parameters of three or more dimensions in a two-dimensional table.

Data used in the GTAP model are contained in header array (HAR) files. You select which dimensions to display in the HAR file by selecting set elements from the dropdown boxes in the upper right corner of the file (Figure ME 2.2). There is one drop down box for each dimension of the variable. In the case of import tariffs, for example, there are three dropdown boxes: TRADE_COMM, countries *s,* and countries *r*. (If the variable has only two dimensions, only two dropdown boxes appear in the upper right

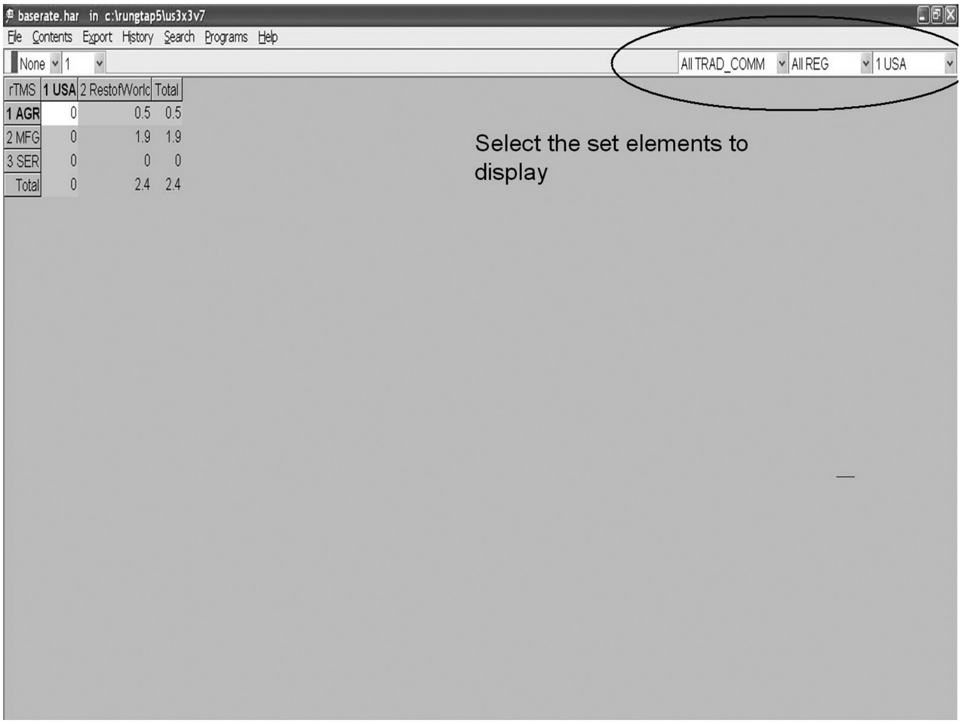


Figure ME 2.2. Select the set elements to display

corner of the file.) Note the set name convention in the GTAP model – country *s,* usually the first country in a variable name, is always the exporter, or source country, of a traded good; and country *r,* usually the second country in the variable name, is always the importing, or destination, country of a traded good.

In the steps below, we show how to view in a table the U.S. import tariff rates on each commodity from each of its trade partners. In this case, we want to display data for all traded goods (TRAD_COMM) and all source countries, s. We will display data for only one importing country, *r*, which is the United States.

In RunGTAP:

> Select "View" from the menu bar
> Select "Base data" from the dropdown menu
> Select "Tax rates" from the dropdown menu
> Select "rTMS" (the last row), which reports import tariff rates

> In the upper right corner of the HAR file, the left side box is ALL TRAD_COMM. Its dropdown box displays all elements of this set: AGR, MFG and SER. Select "All TRAD_Comm." This selection means that data for every traded commodity will be reported in the table.

> In the upper right corner of the HAR file, the center box is ALL_REG. Its drop down box displays all elements of set *s*, the source country for imports. In our model, the set *s* includes the USA and ROW. Select "ALL_REG." This selection means that all source regions will be reported in the table.
> In the upper right corner of the HAR file, the right side box is Sum REG. Its drop down box displays all elements of set r, the destination country for imports. Select "USA." This selection means that data for only one element of set *r* will be displayed.
> Experiment with selecting other elements of set *r*, in the right hand drop down menu. What happens if you select "ALL REG"?
> Close the base rate HAR file by clicking on the red X in the upper right corner.

D. Explore the Elasticity Parameters

In RunGTAP:

> Select "View" from the menu bar.
> Select "Parameters" from the dropdown menu. This har file contains all of the elasticities used in model equations.
> Select INCPAR (row 3).
> What is the INCPAR parameter for U.S. services?
> INCPAR("USA", "SER") = __________
> Double click anywhere in the file to return to the list of parameters.
> Report the elasticities for U.S. agriculture in Table ME 2.1.
> Close the default.prm file by clicking on the red X in the upper right corner.

E. Explore the Tax Rate Parameters

In RunGTAP:

> Select "View" from the menu bar.
> Select "Base data" from the dropdown menu.

Table ME 2.1. *Elasticity Parameters for U.S. Agriculture*

Elasticity	Value
Supply parameters	
Factor substitution (ESUBVA)	0.2
Intermediate input substitution (ESUBT)	
Demand parameters	
Consumer income (INCPAR)	
Consumer substitution (SUBPAR)	
Import substitution (imports v. domestic good) (ESUBD)	
Import substitution (among trade partners) (ESUBM)	

Table ME 2.2. *Tax Rates for U.S. Agriculture*

Tax rate	Name	Value
rTO	% ad valorem output (or income) subsidy in region r	
rTF		
rTPD		
rTPI		
rTGD		
rTGI		
rTFD		
rTFI		
rTXS		
rTMS		

> Select "Tax rates" from the dropdown menu. This HAR file reports all of the tax rates in the GTAP model.
> Double-click on the rTO (first row) to display the output (or income) tax rate.
> In the Table 2.2, report the production tax rate for U.S. agriculture (a negative rate denotes a subsidy).
> Write the names of all of the other taxes in the GTAP model in Table 2.2.
> For each tax, report the tax rate for U.S. agriculture in Table 2.2.
> Be careful to check the dimensions in the upper right corner of the HAR files. In the case of export and import taxes, which are three dimensional parameters, report the export tax on agricultural goods shipped from the U.S. to ROW; and the import tariff on agricultural goods shipped from ROW to the United States.
> Close the base rates HAR file by clicking on the red x in the upper right corner of the file.

F. Explore Model Closure

Model closure defines which variables are endogenous and which variables are exogenous, or fixed.

1. Find the Variable Names and Definitions in the GTAP Model

In RunGTAP:

> Select "View" from the menu bar
> Select "Variables and subsets" from the dropdown menu
> Select "Variables" from the folder tabs in the information file.

Write the definition of the following variables:

pm ________________________________
pop ________________________________
ps ________________________________
qfe ________________________________

qiw ______________________________________

qxw ______________________________________

> Close the information HAR file by clicking on the red x in the upper rifht corner of the file.

2. Find the Model Closure Statement and Identify the Endogenous and Exogenous Variables

The GTAP model assumes that all model variables are endogenous unless they are explicitly defined to be exogenous. To see which variables are defined as exogenous:

In RunGTAP:

> Select "Closure" from the page tabs.

Which of the variables listed in F.1 above are exogenous? Which are endogenous?

Exogenous: ______________________________________

Endogenous: ______________________________________

G. Explore the Equations in the GTAP Model

You will become more familiar with the equations of the GTAP model as you gain experience in running the model and analyzing your results. For now, just open the GTAP model's underlying programming code and find the roadmap that describes how equations are organized into blocks of model code:

In RunGTAP, select:

> "View" from the menu bar
> "Tab files" from the dropdown menu
> "Main model" (this command displays the programming code of the main GTAP model.)

Search for the term "Overview of the GTAP.TAB Structure," by selecting:

> Search
> Find
> Enter the search term in the search box.

This section of the model describes the organization of the modeling code in the GTAP model into preliminaries, modules with economic equations, and the calculation of welfare effects using model results.

H. Explore Market-Clearing Constraints

Still in the GTAP.tab file, search for an identity equation that is an example of a market-clearing constraint that ensures that the model's results describe an economic equilibrium in supply and demand. In the search box, enter the term:

"MKTCLDOM"

This equation imposes the constraint that, in each country, the total domestically produced supply of each good is equal to the sum of demand for that good by firms, households, and government.

Model Exercise 3: Run the GTAP Model

Concepts: Define and run experiments, change elasticity parameters and model closure, read model results, use GTAP utilities for welfare decomposition and systematic sensitivity analysis

In this exercise, you will learn to define and run a model experiment (called a "shock"), and to search for and report model results. You will learn how to change an elasticity parameter, change a model closure, and export and compare results. This exercise also shows you how to use GTAP utilities for welfare decomposition and for a systematic sensitivity analysis with respect to elasticity parameters. Model Exercise 3 is designed to serve as a reference that you can turn back to for basic directions as you carry out exercises 4–8. In this exercise, we focus only on the mechanics of using and controlling the GTAP model; we study the economic behavior in the model in exercises 4–9.

A. Open GTAP Model with U.S. 3x3 Database

This step opens the "version" of the GTAP model that uses the U.S. 3x3 database. You created this version of the model in Exercise 1.

1. Open RunGTAP
2. On the upper menu bar, choose Version
   > Select "Change" from the dropdown menu. This opens a list of model versions.
   > Select US3x3
   > OK (this changes the database, or version, used in the GTAP model.)

B. Prepare Your Model to Define and Run an Experiment

The following housekeeping steps may not always be necessary but, like a pilot's preflight check list, it is a good practice to follow them before defining or running any model shock.

1. Prepare your model to define an experiment – check closure
   > Select the Closure page tab.

Check that no closure changes are lingering there. The closure should end with "Rest Endogenous." If not, erase all text below that line.

2. Prepare your model to define an experiment – check shocks
   > Select Shocks page tab
   > Clear shock list

This check ensures that there are no shocks lingering in your experiment file other than those you want to introduce.

3. Check the elasticity parameter file
   > Select Solve page tab
   > Check that the parameter file named in the upper right corner is your preferred file (in this exercise, let it remain as the default parameter file).
4. Check model solution method
   > Select Solve page tab
   > Solution Method (in the upper right corner of the page): select "Change"
   > Choose "Gragg" solution method. (Your choice of solution method may vary; this is the method we use for this exercise. It divides the shock into smaller shocks which the model solves sequentially.)
   > OK (this selects the new solution method)

C. *Define a Model Experiment Using the "Shocks" Page*

In this exercise, you will introduce a 5 percent output subsidy to U.S. manufacturing. Experiments are defined on the "Shocks" page (see Figure ME 3.1).

1. Select the "Shocks" page tab
   > Select from the "Variable to Shock" dropdown menu: *to*
   > Select from the "Elements to Shock" dropdown menu: MFG
   > Select from the Region dropdown menu: USA

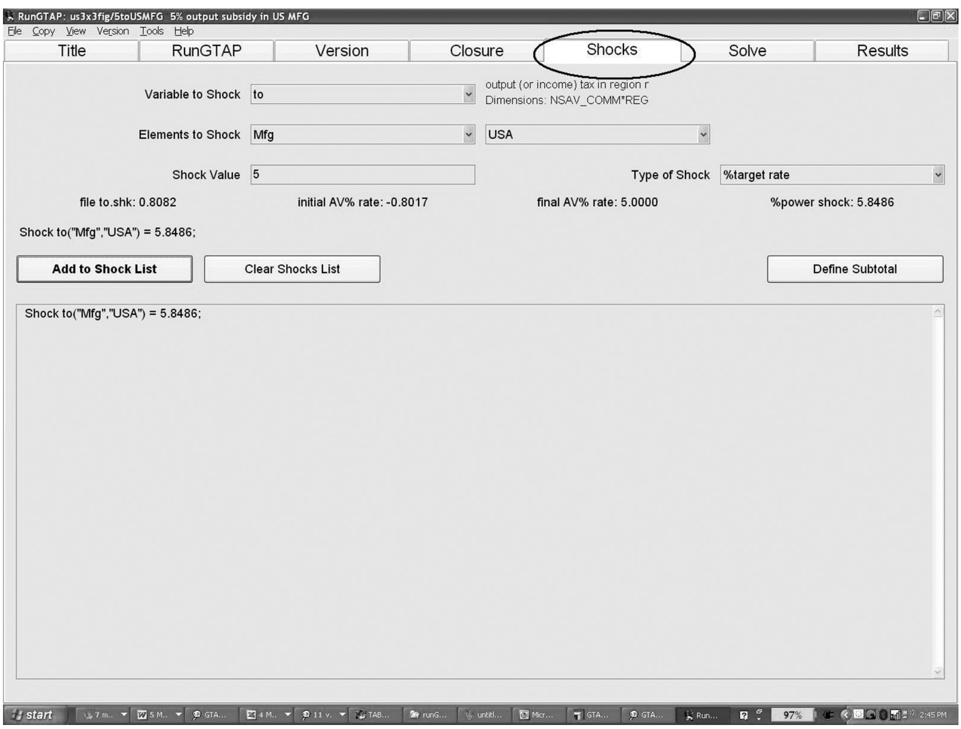


Figure ME 3.1. Shocks page

> For "Shock Value" enter: 5 (positive value is a subsidy, negative is a tax)
> Select from the "Type of Shock" dropdown menu: % target rate
> Click on "Add to shock list."
> Verify that the shock to the U.S. production tax is the only shock in the shocks list

2. What is the definition of "to"? ___________________________
3. What is the initial *ad valorem* (AV) tax rate of "to" in U.S. manufacturing? _________
4. Is the initial rate of "to" a subsidy or a tax? _________________

D. Save a Model Experiment and Solve the Model

Select the "Solve" page tab:

1. Save the experiment file
   > Check solution method. It should be Gragg 2-4-6. If it is not, click on "Change," select Gragg and then click on "OK"
   > Check parameter file. It should be "Default." If it is not, click on "Change," select "Default" from the box and click on "OK"
   > Click on "Save experiment"
   > Name the experiment: 5toUSMFG (see Figure ME 3.2)
   > Description: "5% output subsidy in U.S. MFG"
   > OK (this saves the experiment file)

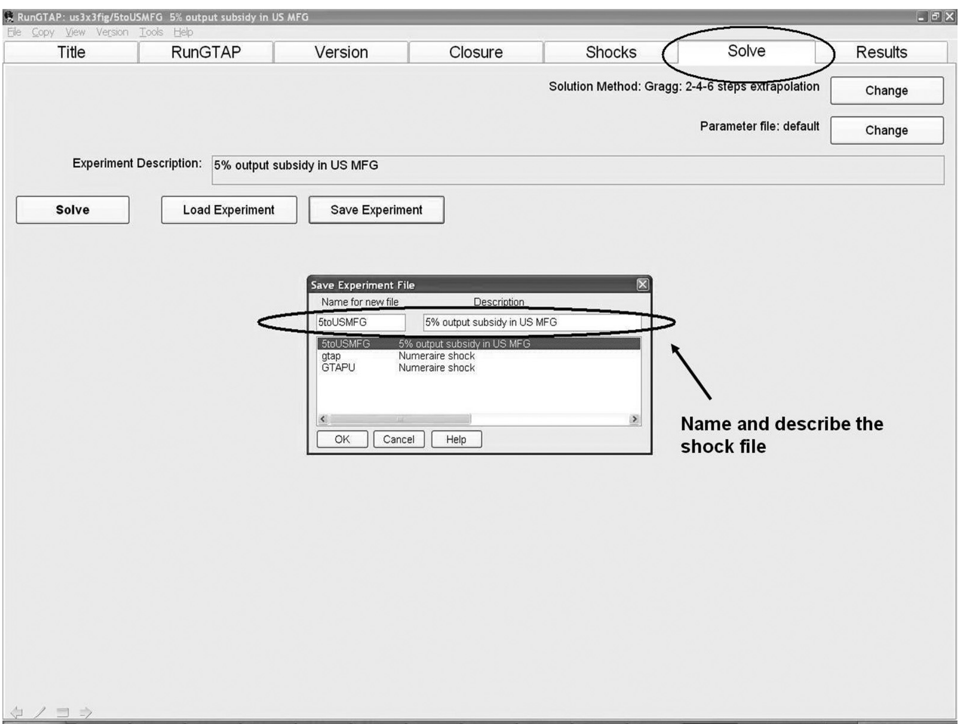


Figure ME 3.2. Solve page

2. Solve the model
   > Still on the Solve page, click on the “Solve” button
   > OK (this closes the accuracy summary report box)
   > OK (this closes a solution information box)
3. Verify that your tax shock was what you think it is. Select:
   > “View” from the menu bar
   > “Updated data” from the dropdown menu
   > Updated tax rates
   > Click on the first row, rTO, to view the rTO matrix and then check the entry for column “USA” and row “MFG”
   > Confirm that rTO for USA MFG is now 5.0. (Note that in this display, a negative value is a tax and a positive value is a subsidy.)
   > Close the file by clicking on the red X in the upper right corner

E. Find and Report Experiment Results

Model results for most variables in the model are reported on the Result page, which is opened by clicking on the Results page tab (Figure ME 3.3). GTAP’s naming convention is to use lower case letters to denote a variable reported as a percentage change from base values, and upper case to denote

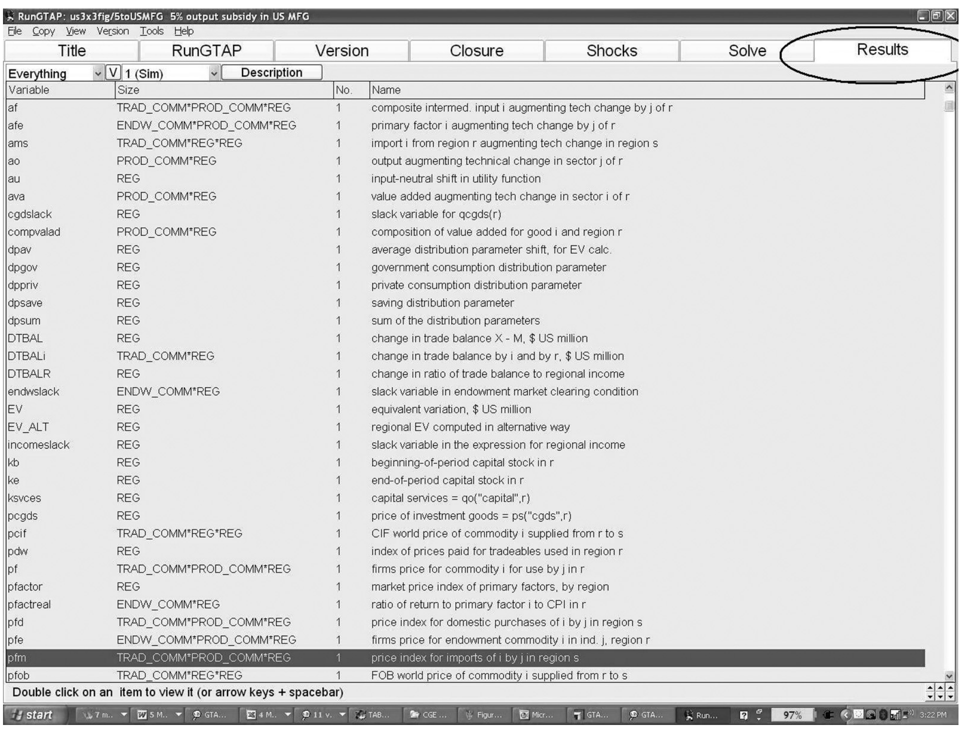


Figure ME 3.3. Results page

Table ME 3.1. *Results of a 5 Percent Production Subsidy in U.S. Manufacturing, with Different Elasticities and Closures*

	Definition of Variable	Base Results	High Substitution Elasticity	Unemployment Closure
qo("MFG", "USA")				
qo("MFG", "ROW")				
qfe("LABOR", "MFG", "USA")				

Source: GTAP model, GTAP v.7.0 U.S. 3x3 database.

a variable reported in levels. For example, variables in lower case, such as *ps* or *pm*, are the percentage changes in the supply price and market price of a good, respectively. The variable DTBAL is the change in a country's trade balance, reported in $U.S. millions.

1. Find a variable result on the "Results" page
   > Select the Results page tab. (Variables are listed in alphabetical order).
   > Write the definition of the variable *qo("MFG","USA")* in Table 3.1
   > Double-click on variable *qo*
   > Report the result for variable *qo("MFG","USA")* in the United States in the "base results" column of Table 3.1
   > Report the result for manufacturing output in ROW in the "Base results" column of Table 3.1
   > Double-click on data anywhere in the table to return to the variable list

2. Display results of variables with three dimensions using data filter

Tables are two-dimensional displays of data but some variables have more than two dimensions. For example, variable *qfe(i,j,r)* has three dimensions: the quantity of factor *i* used in industry *j* in country *r*. To display results for variable *qfe*, use the data filter in the upper left corner of the results page to select the dimensions to control and the dimensions to display (see Figure ME 3.4). In the example below, you will control dimension r by selecting "USA," so that the variable *qfe(i,j,"USA")* is displayed in a table with a dimension of *i* by *j*.

> Double-click on variable *qfe* – you'll get an error – "Sorry, you cannot view a 3-D matrix."
> From the dropdown menu on the upper left side, which says "Everything" choose "USA" – this controls set *r* so that sets *i* and *j* can be displayed
> Double-click on variable *qfe* and report results for labor demand in MFG for the USA in the "Base results" column of Table ME 3.1
> Double-click on data anywhere in the table to return to the variable list.

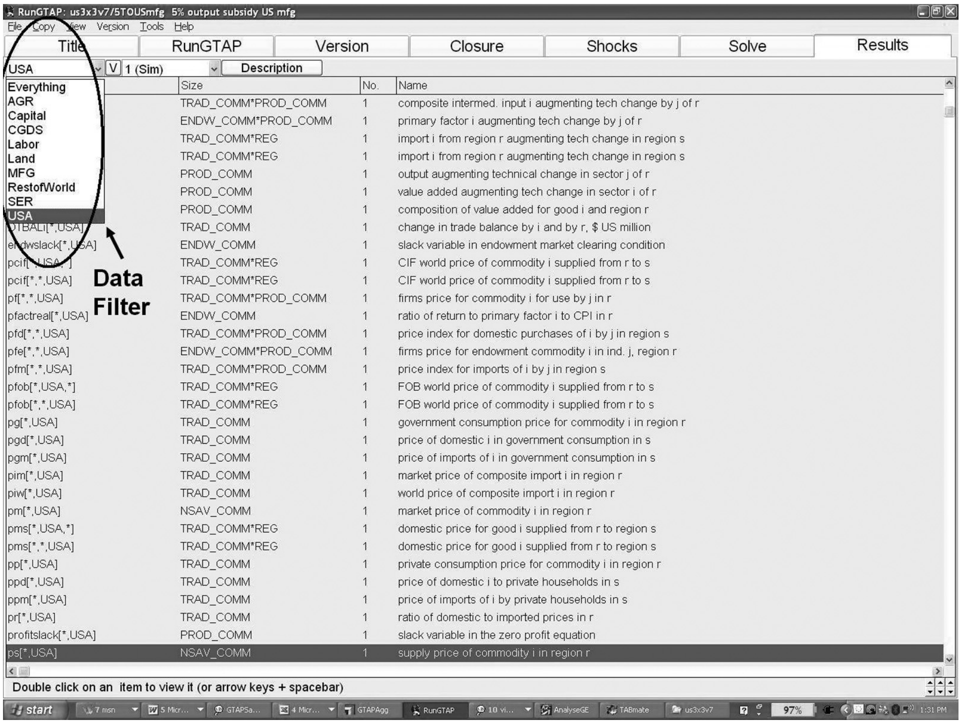


Figure ME 3.4. Data filter on the results page

F. Find and Report Welfare Decomposition Results

The GTAP model includes a utility that decomposes the equivalent variation (EV) welfare effect of an economic shock. We discuss welfare measures in detail in Chapter 6. The utility disaggregates the total welfare effect into six components: resource allocation (efficiency) effects (the excess burden of taxes), endowment effects due to changes in factor supplies, technical change due to productivity gains or losses, the effects of population growth, changes in terms of trade for goods and for savings and investment flows, and changes in preferences (the structure of aggregate demand). Welfare effects are reported in levels, in $ U.S. millions.

1. Open the GTAP welfare decomposition utility:
   > Select "View" from the menu bar
   > Select "Updated Data" from the dropdown menu
   > Select "Welfare Decomposition" from the dropdown menu

This page lists the full decomposition of EV (Figure ME 3.5).

2. View the summary of the welfare decomposition.
   > Double click on first row: EV Decomposition Summary.

Table ME 3.2. *Welfare Decomposition of a 5 Percent Production Subsidy in U.S. Agriculture*

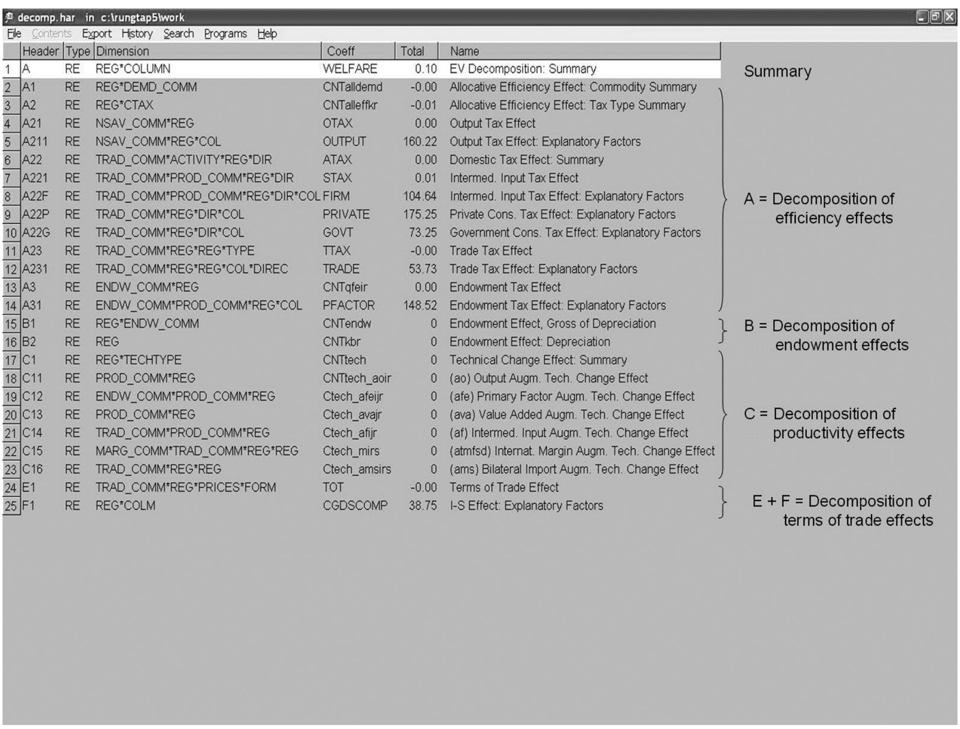
Resource Allocation Effect	Endowment Effect	Technical Change	Population Growth	Terms of Trade	Investment-Savings Terms of Trade	Preference Change	Total
1 alloc_A1 7,399.7	2 endw_B1	3 tech_C1	4 pop_D1	5 tot_E1	6 IS_F1	7 pref_G1	

Source: GTAP model, GTAP v.7.0 U.S. 3x3 database.

> Report the welfare impacts of the 5 percent output subsidy in U.S. manufacturing in Table ME 3.2. As a check, the first element, "Resource allocation effect," is already reported in the table.
> Double click anywhere on the page to return to the main EV decomposition page.

3. View the detailed welfare decomposition

The main welfare decomposition page, shown in Figure ME 3.5, lists all available decompositions. For example, all of rows with headers names that begin with A list decompositions of allocative efficiency effects, by type of tax, and by commodity. All rows with a header name that starts with C



	Header	Type	Dimension	Coeff	Total	Name
1	A	RE	REG*COLUMN	WELFARE	0.10	EV Decomposition: Summary
2	A1	RE	REG*DEMD_COMM	CNTalldemd	-0.00	Allocative Efficiency Effect: Commodity Summary
3	A2	RE	REG*CTAX	CNTalleffkr	-0.01	Allocative Efficiency Effect: Tax Type Summary
4	A21	RE	NSAV_COMM*REG	OTAX	0.00	Output Tax Effect
5	A211	RE	NSAV_COMM*REG*COL	OUTPUT	160.22	Output Tax Effect: Explanatory Factors
6	A22	RE	TRAD_COMM*ACTIVITY*REG*DIR	ATAX	0.00	Domestic Tax Effect: Summary
7	A221	RE	TRAD_COMM*PROD_COMM*REG*DIR	STAX	0.01	Intermed. Input Tax Effect
8	A22F	RE	TRAD_COMM*PROD_COMM*REG*DIR*COL	FIRM	104.64	Intermed. Input Tax Effect: Explanatory Factors
9	A22P	RE	TRAD_COMM*REG*DIR*COL	PRIVATE	175.25	Private Cons. Tax Effect: Explanatory Factors
10	A22G	RE	TRAD_COMM*REG*DIR*COL	GOVT	73.25	Government Cons. Tax Effect: Explanatory Factors
11	A23	RE	TRAD_COMM*REG*REG*TYPE	TTAX	-0.00	Trade Tax Effect
12	A231	RE	TRAD_COMM*REG*REG*COL*DIREC	TRADE	53.73	Trade Tax Effect: Explanatory Factors
13	A3	RE	ENDW_COMM*REG	CNTqfeir	0.00	Endowment Tax Effect
14	A31	RE	ENDW_COMM*PROD_COMM*REG*COL	PFACTOR	148.52	Endowment Tax Effect: Explanatory Factors
15	B1	RE	REG*ENDW_COMM	CNTendw	0	Endowment Effect, Gross of Depreciation
16	B2	RE	REG	CNTkbr	0	Endowment Effect: Depreciation
17	C1	RE	REG*TECHTYPE	CNTtech	0	Technical Change Effect: Summary
18	C11	RE	PROD_COMM*REG	CNTtech_aoir	0	(ao) Output Augm. Tech. Change Effect
19	C12	RE	ENDW_COMM*PROD_COMM*REG	Ctech_afeijr	0	(afe) Primary Factor Augm. Tech. Change Effect
20	C13	RE	PROD_COMM*REG	Ctech_avajr	0	(ava) Value Added Augm. Tech. Change Effect
21	C14	RE	TRAD_COMM*PROD_COMM*REG	Ctech_afijr	0	(af) Intermed. Input Augm. Tech. Change Effect
22	C15	RE	MARG_COMM*TRAD_COMM*REG*REG	Ctech_mirs	0	(atmfsd) Internat. Margin Augm. Tech. Change Effect
23	C16	RE	TRAD_COMM*REG*REG	Ctech_amsirs	0	(ams) Bilateral Import Augm. Tech. Change Effect
24	E1	RE	TRAD_COMM*REG*PRICES*FORM	TOT	-0.00	Terms of Trade Effect
25	F1	RE	REG*COLM	CGDSCOMP	38.75	I-S Effect: Explanatory Factors

Figure ME 3.5. Welfare decomposition utility in the GTAP model list decompositions of the productivity effect, and so on. You can view any decomposition in the list by clicking on it.

G. Export Model Results to Excel

You may want to compare the results of two experiments but the GTAP model only reports results for one experiment at a time. The easiest way to save and compare selected results is to export results, one variable at a time, to your clipboard and paste them into an Excel file that identifies the experiment that generated the results.

After running an experiment,

> Select the "Results" page tab
> Double click on the variable that you want to display
> Select "Copy" from the upper menu bar (this copies the results to your clipboard)
> Open Excel and paste your results into your file.
> Label the results with the name of your experiment.

H. View and Change an Elasticity Parameter

Elasticities are the exogenous parameters used in model equations to define the responsiveness of supply and demand to changes in prices or income. A change to an elasticity parameter is not an experiment or "shock." It changes the model itself and how producers and consumers are assumed to respond to a shock. For instance, you might define a shock to be a new tariff on imports. You can run the experiment using the model's base elasticity values, and then run it again using a model with larger or smaller elasticity values. You then compare the results of the *same experiment* across two (or more) models with different assumed elasticity values.

This exercise shows you how to change an elasticity in the GTAP model from its default values and save it in a new parameter file. In this example, you will change the factor substitution elasticity in U.S. manufacturing. Note that in the GTAP model, the factor substitution elasticity for each industry is the same for all countries in the model. You can use these same steps to change any elasticity in the GTAP model.

1. Define the new parameter values
   > Select "View" on the menu bar
   > Click on "Parameters" from the dropdown menu
   > Double click on ESUBVA (the elasticity of factor substitution) row.
   > Right click on the data entry for MFG ESBUVA (see Figure ME 3.6)
   > Enter new ESUBVA value in manufacturing of "5"

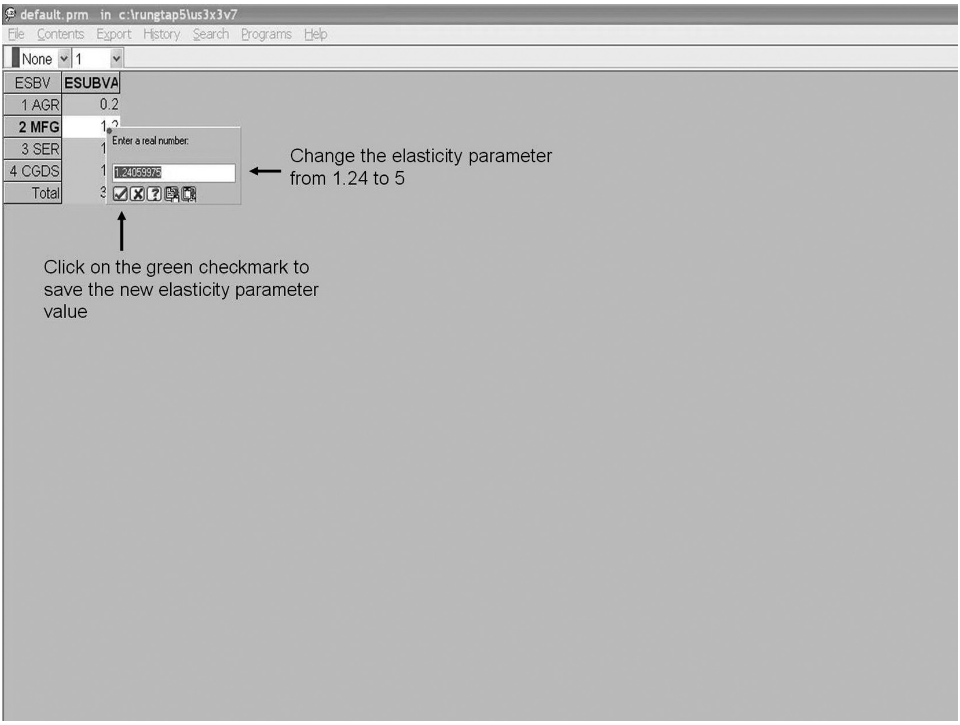


Figure ME 3.6. Changing an elasticity parameter

> Click on the green check mark to save the new elasticity parameter value on this sheet. But be careful, this does not save a new parameter file – see the next step (You may get an error message that "You modified the file but need a GEMPACK license." You may safely ignore the warning for this exercise.)

2. Save your new parameter file
   > Select "File" (in the ESUBVA window).
   > Close
   > Yes (answers the prompt, Save Changes?)
   > IMPORTANT do not overwrite your default parameter file. In the box, provide a new file name with a .prm suffix, such as "5vaMFG.prm"
   > Click on "Save." This step saves your new parameters in a file in your model version folder in the RunGTAP5 directory
   > OK
3. Re-solve the model with a new elasticity
   > Select "Solve" page tab.
   > Check that the experiment description box describes "5toMFG," which means that your experiment is loaded and ready to run
   > If a different experiment is described, select "Load Experiment" and click on "5toMFG" and then click on OK to load the experiment 5toMFG
   > Click on "Change" next to "Parameter file:Default" in the upper right corner of the page

> Select the name of your new parameter file: 5vaMFG
> OK (Your experiment file will now always use your new parameter file unless you change this selection.)

You have two options for saving your experiment and parameter file. One is to save a new version of your experiment, with a new name, which signals that this experiment uses a different parameter file. In the next several steps, we describe how to do this. Because this can create file clutter, an alternative is to reuse a single experiment, always checking to see which parameter file is specified. That is the approach we follow in the remaining model exercises.

> Click on "Save Experiment"
> Give your experiment a new name, to indicate that this version uses different elasticity parameters than your original experiment. Name it something like: "5toMFG2" and describe it as "5toMFG with 5 ESUBVA in Mfg"
> OK
> Solve

4. Report new model results in Table ME 3.1, following the same instructions as in section E of this model exercise.

I. Change Model Closure

Model closure statements define which variables adjust (i.e., which are endogenous) and which are fixed (i.e., which are exogenous). To modify the model's standard closure statements, you must "swap" an exogenous variable for an endogenous variable. This swap preserves the same number of endogenous variables that were originally in the model.

In this exercise section, you will modify the labor market closure. The default closure has an exogenous, fixed national supply of labor (*qo*) and an endogenous economywide wage (*ps*). You will change the closure to swap the labor supply variable with the wage variable . Note that we are changing the closure statement for one factor market (labor) in one country (USA), as shown in Figure ME 3.7.

1. Select the Solve page tab
   > Open the experiment file "5toMFG"
   > Click on the "Load Experiment" button
   > Select the experiment "5toMFG"
   > OK
2. Select the "Closure" page tab
   > Insert the bolded text below the final line of the closure instructions – "Rest Endogenous" (see Figure ME 3.7):
   > **swap qo("labor","USA") = ps("labor","USA");**

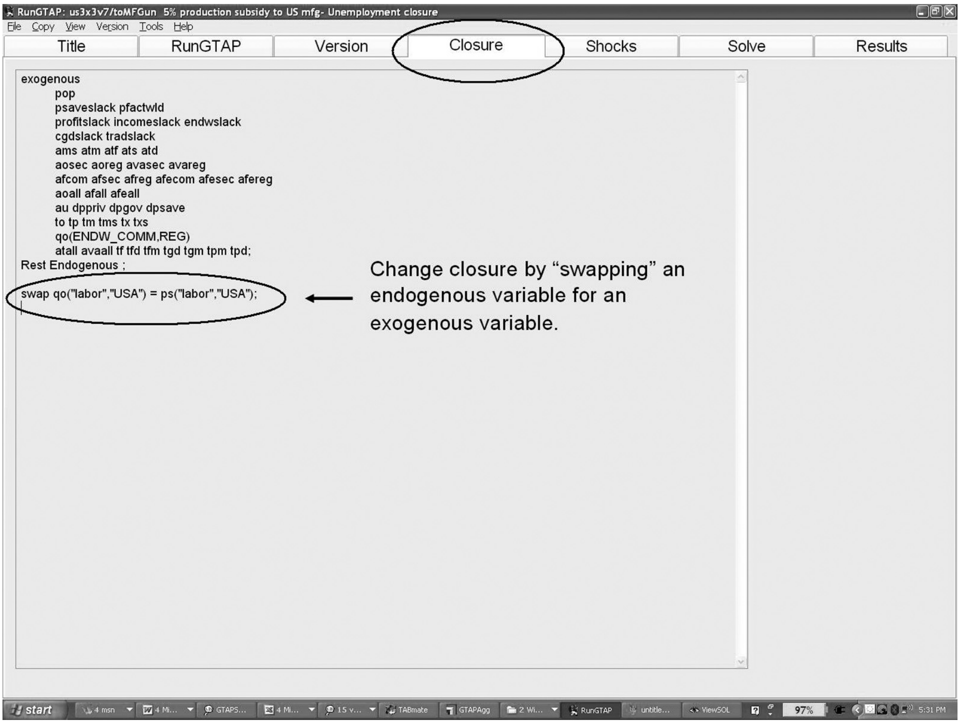


Figure ME 3.7. Changing the labor market closure

3. Select the "Solve" page tab
   > Save experiment
   > Name it "toMFGun" and describe it as "5% output subsidy to US MFG with unemployment." This step saves both the experiment and the new closure statement. You can now rerun this experiment at any time without having to respecify your new closure statement.
   > OK
   > Solve
   > OK
   > OK
   > Report new model results in Table ME 3.1.
4. Do results of your experiment change when the elasticity or model closure statement changes?

Table ME 3.3 lists commonly used closure modifications in the GTAP and their related swap statements.

J. Systematic Sensitivity Analysis and Stochastic Shocks

The GTAP model includes a utility developed by Arndt and Pearson (1998) that automates a systematic analysis of the sensitivity of model results to the assumed values of elasticity parameters or to the size of an experiment

Table ME 3.3. *Commonly Modified Closures in the GTAP Model*

Closure in GTAP Model	Explanation	Add this Model Code to Closure Statement
Factor unemployment	For a specified country *r* and factor *f*, allows the endowment of a factor to vary and fixes that factor's price.	swap qo(f,r) = ps(f,r); *example:* *swap qo("labor","USA") = ps("labor","USA");*
Fixed balance of trade	For a specified country *r*, allows domestic savings to adjust to maintain a fixed ratio between the trade balance and national income.	Swap dpsave(r) = DTBALR(r); *example:* *swap dpsave("usa") = DTBALR("usa");*
Fixed world import price (small country assumption for country r)	For a specified country *r,* fixes world import prices (*pm* in trade partner, *s*) by swapping several slack variables in the trade partner country.	*Example:* *Closure to fix world price – pm in ROW* *swap walraslack = pfactwld;* *swap incomeslack("ROW") = y("ROW");* *swap profitslack(PROD_COMM,"ROW") = qo(PROD_COMM,"ROW");* *swap endwslack(ENDW_COMM,"ROW") = pm(ENDW_COMM,"ROW");* *swap tradslack(TRAD_COMM,"ROW") = pm(TRAD_COMM,"ROW");* *swap cgdslack("ROW") = pm(CGDS_COMM,"ROW");*
Tax replacement or balanced government budget	For a specified country *r*, sales tax on private commodity consumption (imports plus domestic) becomes endogenous to maintain a fixed ratio of indirect tax revenue to national income.	swap tp(r) = del_ttaxr(r); *example:* *swap tp("usa") = del_ttaxr("usa");*
Export quantity control	For a specified commodity and bilateral trade flow, fixes export supply to partner; endogenous export tax measures economic rent to exporting country.	swap qxs(i,r,s) = txs(i,r,s); *example:* *qxs("mfg", "usa", "row") = txs("mfg", "usa", "row");*
Import quantity control	For a specified commodity *i* and importing country *r*, an endogenous import tariff maintains fixed import quantity.	swap qiw(i,s) = tm(i,s); *example:* *swap qiw("mfg","usa") = tm("mfg","usa");*
Variable import levy	For a specified commodity *i* and importing country *r*, an endogenous import tariff maintains a fixed ratio between the domestic market price and its world import price	Swap pr(i,r) = tm(i,r); *example:* *swap pr("mfg","usa") = tm("mfg","usa");*
Insulate domestic production levels from world market conditions	For a specified commodity *i* and country *r*, an endogenous export subsidy varies to maintain a fixed domestic production level.	swap qo(i,s) = tx(i,s); *example:* *swap qo("mfg","usa") = tx("mfg","usa");*

Text Box ME 3.1. Chebyshev's Theorem

At least the fraction $(1 - (1/k^2)$ of any set of observations lies within k standard deviations of the mean, therefore:

a. 75% of the observations are contained in the interval $\overline{x} \pm 2sd$
b. 88.9% of the observations are contained in the interval $\overline{x} \pm 3sd$
c. 95% of the observations are contained in the interval $\overline{x} \pm 4.47sd$
d. 99% of the observations are contained in the interval $\overline{x} \pm 10sd$

shock.[2] To test the sensitivity to elasticity values, the modeler chooses which elasticity parameter(s) to test and specifies the range of values over which each will be tested. For example, the modeler may have assumed a value of two for the import substitution elasticity, but wants to test the sensitivity of model results if its value ranges between 50 and 150 percent. The utility reports an estimate of the mean and standard deviation of results for every variable in the model as the elasticity value ranges between one and three.

A test of the sensitivity of model results to variability in model shocks is carried out in a similar way. In this case, the modeler defines a possible range for the parameter that is being shocked. For example, the modeler may be studying the effects of climate change on productivity in agricultural production, which he has described in the model as a negative 10 percent shock to total output productivity. If estimates of productivity losses vary widely in the literature, the modeler may want to test a range in productivity loss between 50 percent and 150 percent of the 10 percent decline. In this case, the sensitivity analysis would estimate the mean and standard deviation of model results for each variable, as the productivity shock ranges in value between minus 5 percent and minus 15 percent.

You can use the estimated means and standard deviations to calculate confidence intervals for your model result. We use Chebyshev's theorem for these calculations because it does not require us to assume anything about the shape of the probability distribution of the results for each variable (Text Box ME 3.1).

As an example, imagine that you carried out a model experiment for which you assumed an import substitution elasticity value of two, with the result that output of good Q increases 19.1 percent. You then carried out a systematic sensitivity analysis to a range of between 50 and 150 percent of that elasticity value. Suppose your sensitivity analysis reports that the percent change in output of good Q has an estimated mean of nineteen and standard deviation of one. Using Chebyshev's theorem, you can construct a 95 percent confidence interval. For example, the upper limit of a 95 percent

[2] A detailed and intuitive description of the Stochastic Sensitivity Analysis (SSA) utility is available after opening this utility in the GTAP model.

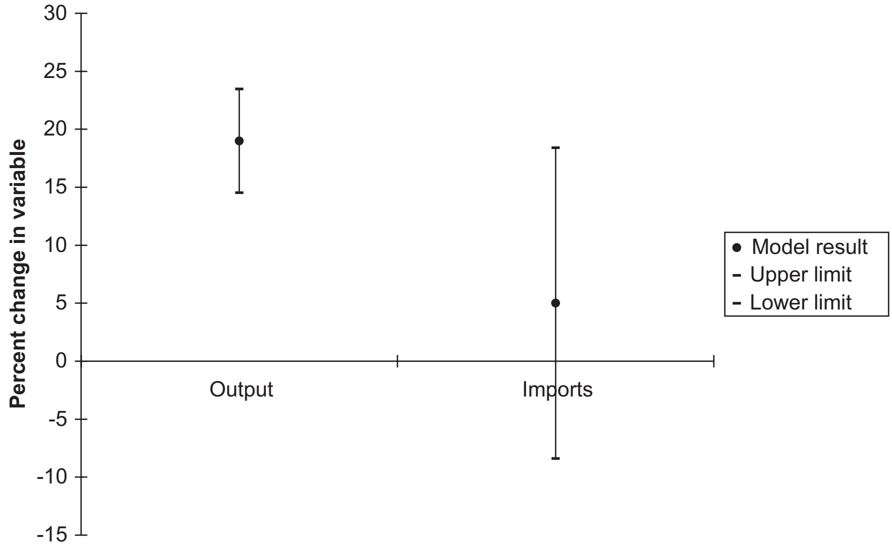


Figure ME 3.8. 95 percent confidence intervals for output and import quantities of good Q

confidence interval is twenty-four , because 19 + (4.47 * 1) = 24. The lower limit is fifteen, because 19 – (4.47 * 1) = 15. Similarly, you can report with 75 percent confidence that the result lies between twenty-one and seventeen, which is nineteen plus or minus two (two times the standard deviation of one), and so forth.

Figure ME 3.8 plots these results on a graph. It shows the point estimate for the percentage change in output, which is the result reported in your model. It also plots the upper and lower limits of the 95 percent confidence interval that we calculated. Plotting model results along with confidence intervals is an effective way to visually communicate information about model sensitivity. In this case, a positive output change is a robust model result over the range that you specified for the value of the import substitution elasticity.

On the other hand, let's assume that your analysis reports a percentage change in the import quantity of good Q of 5 percent, with a mean of five and a standard deviation of three. Using Chebyshev's theorem, you have a 95 percent level of confidence that the percentage change in imports lies between eighteen and minus eight, and a 75 percent level of confidence that the result lies between eleven and minus one. In this case, you cannot be 95 percent confident or even 75 percent confident that imports increase, instead of fall, over your specified range of alternative elasticity parameter values.

The following steps will guide you in carrying out an analysis of the sensitivity of model results to the elasticity of factor substitution. A sensitivity analysis with respect to the size of an experiment shock is analyzed in the same way, so we do not repeat the instructions for that case. Our example is a systematic sensitivity analysis of the results of a 5 percent output

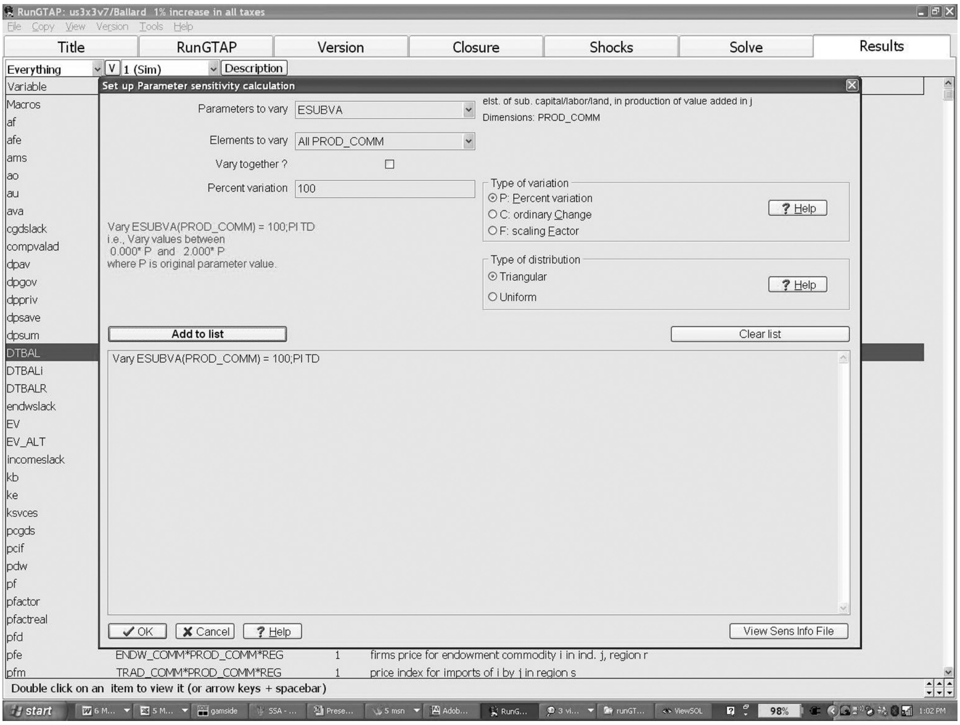


Figure ME 3.9. Systematic sensitivity analysis of an elasticity parameter

subsidy in U.S. manufacturing to the value of the import substitution (ESUBD) elasticity parameter.

1. In runGTAP, reload and rerun your experiment “5toUSMFG.”
   > go the to “Solve” page tab
   > Click on “Load Experiment” button
   > Select “5toUSMFG” experiment
   > OK
   > Check that parameter file to be used is default.prm; if not, click on the “Change” button, select default.prm from the list, and click >OK.
   > Solve
   > OK
   > OK
2. Open the Systematic Sensitivity Analysis utility
   > Select “Tools” from the top menu bar
   > Select Sensitivity
   > Help on sensitivity (This provides documentation and explanation of this utility that you can use as a reference.)
   > Close the help document by clicking on the red X in the upper right corner of the file. This returns you to the GTAP model.
   > “Tools”
   > “Sensitivity”
   > “w.r.t. parameters” (the worksheet shown in Figure ME 3.9 will open)

Table ME 3.4. *Confidence Intervals for the Output Quantity Result with 100 Percent Variation in the Factor Substitution Elasticity*

Confidence Interval	Mean (X)	Standard Deviation (sd)	Standard deviation Multiplier (K)	Upper Limit (X + sdK)	Lower Limit (X − sdK)
75 percent			2		
88.9 percent			3		
95 percent			4.47		
99 percent			10		

> Parameter to vary: ESUBVA
> Elements to vary: ALL PROD_COMM
> Percent variation: 100 (the sensitivity analysis will vary the ESUBVA elasticity parameter value between close to zero and two times the base parameter value
> Type of variation: Percent (this is the default choice)
> Type of distribution: triangular (it is similar to a bell curve distribution and is the default choice)
> Select "Add to list"
> OK
> Select "Stroud" (this is the default choice. It defines the sampling of parameter values within the range that you specified.)
> OK (this starts the analysis)
> Yes (to the prompt, do you want to save the two solutions reporting means and deviations?)
> OK (to the prompt asking you to name the two report files)
> Replace the star in the file name with "5toUSMFG" – without the quotes. The files with the means and deviations will be named: 5toUSMFGm1.sl4 and 5toUSMFGsd.sl4.
> Yes (this opens ViewSol utility, used to view the files with the sensitivity analysis results)

3. Report results from the ViewSol file for U.S. manufacturing output, *qo*("MFG", "USA").
   a. Model result (reported in first column of data) _______________
   b. Mean (m1 – reported in second column of data) ________________
   c. Standard deviation (sd – reported in third column of data) ________________
4. Construct confidence intervals using Chebyshev's Theorem, following the example in the first row of the table. Report them in Table ME 3.4. What is your level of confidence that the effect on U.S. manufacturing output is positive?

Model Exercise 4: Soaring Food Prices and the U.S. Economy

Concepts: Utility function, Armington import demand, small-country closure

Background

In 2008, the prices of major agricultural commodities soared by more than 60 percent compared to their 2006 levels, after many years of relative price stability (Trostle, 2008). Prices abated when the global economy entered a recession, but some analysts view this price decline as temporary. They anticipate a long-term trend of rising food prices as future growth in global food demand outpaces growth in global supply.

Both short and long term factors were at play in the skyrocketing of prices during 2008, according to Jeffrey Sachs, a noted Harvard economist writing for *Scientific American*. On the demand side, rising world incomes have led to a steady increase in the demand for grains because increased affluence leads to higher demand for meat. More grain must be used as feed, and the grain-to-food conversion ratio for meat is lower than when grain is consumed directly in products such as bread. China's rapid economic growth and the rising share of meat in the Chinese diet has been a major factor in this trend. Rising demand for feed affects not only the food-feed trade-off for grains; it has also led farmers around the world to grow more of the other necessary livestock feedstuffs such as soybeans, instead of grains. On the supply side, short-term supply shocks that influenced prices in 2008 included Australia's deep drought and the U.S. policy to use corn for ethanol. In the longer term, climate change due to rising world temperatures is expected to change the suitability of land for its traditional agricultural uses, possibly leading to lower productivity in the supply of food.

Given the multiple causes of the potential imbalance between world supply and demand for food in the long term, economists have called for multipronged solutions (Cline, 2007; Collier, 2008). Their proposals include increasing research to raise agricultural productivity, particularly in developing countries where climate change is expected to have the most severe consequences for farming. Other recommendations are for policy change in the United States to end the diversion of corn into ethanol; an end to the European Union ban on imports of high-productivity, genetically modified food products; and global action on mitigating the long-term threat of climate change.

How will long-term rising food prices affect U.S. households' demand for food and the composition of their consumption basket? Will U.S. welfare rise or fall? How might this demand shift affect U.S. industry structure and trade? In this exercise, you will simulate a 50 percent increase in the world price of agricultural products imported to the United States and use your model results to answer these and other questions. You will also analyze the sensitivity of your results to alternative assumptions about U.S. consumer preferences.

Experiment Design

You will run a single model experiment – a 50 percent increase in the global price of agricultural products. This experiment will require you to change the GTAP model closure to fix market prices in the rest-of-world region. This closure implies that the United States is too small in the world markets to affect global price levels. The size of the price shock is slightly smaller than the 60 percent world price increase reported by Trostle (2008). We scale the price effect downward because our single agricultural sector includes commodities and natural resources not studied by Trostle; but for illustrative purposes, we still assume a relatively large price shock.

You will run the same model experiment when assuming two different utility functions. In the first experiment, scenario 1, you will use the GTAP model's, CDE demand system with the default consumer demand elasticity parameters in the U.S. 3x3 database. (INCPAR is the income parameter and SUBPAR is the compensated, own-price demand parameter.) In scenario 2, you will modify the consumer's utility function by changing the INCPAR and SUBPAR parameters to replicate those of a Cobb-Douglas utility function.

Instructions

1. Open GTAP model with U.S. 3x3 database

This step opens the "version" of the GTAP model that uses the U.S. 3x3 database. You created this version of the model in Model Exercise 1.

> Open RUNGTAP
> On the top menu bar, choose "Version"
> "Change"
> Select "US3x3"
> OK

2. Prepare your model to run an experiment – check closure
> Select the "Closure" page tab.

Check that no closure changes are lingering there. The closure should end with "Rest Endogenous." If not, erase all text below that line.

3. Prepare your model to run an experiment – check shocks
> Select "Shocks" page tab
> Clear shock list

Table ME 4.1. *Elasticities in Two Scenarios of a 50 Percent Increase in the World Agricultural Price*

	Scenario 1		Scenario 2	
Elasticities	INCPAR	SUBPAR	INCPAR	SUBPAR
Agriculture				
Manufacturing				
Services				

This check ensures that there are no shocks lingering in your experiment file other than those you want to introduce.

4. In Table ME 4.1, report your model's base parameter values for INCPAR and SUBPAR for the United States for scenario 1. (See Model Exercise 2 for instructions on exploring elasticity parameters.)
5. In Table ME 4.2, report base budget shares of each commodity in household expenditure.
   > Select "View" from the upper menu bar
   > "Base data" from the dropdown menu
   > "GTAPView Output"
   > "NVPA" (Row 16) this reports commodity composition of household consumption
   > Open the dropdown menu at top left, next to the box that says "None"
   > Select "COL" from the dropdown box This reports each cell as a percentage of the column total. In this case, the matrix now reports the shares of each commodity in total private household spending. Report the data for the U.S. household.
6. Change the model closure to fix the world price (*pm*) of AGR in the rest-of-world by adding these lines of code to the Closure page, following the final line "Rest Endogenous." (See Model Exercise 3 for instructions on changing model closure.)

   swap walraslack = pfactwld;
   swap incomeslack("ROW") = y("ROW");
   swap profitslack(PROD_COMM,""ROW") = qo(PROD_COMM,"ROW");
   swap endwslack(ENDW_COMM,"ROW") = pm(ENDW_COMM, "ROW");
   swap tradslack(TRAD_COMM, "ROW") = pm(TRAD_COMM,"ROW");
   swap cgdslack("ROW") = pm(CGDS_COMM,"ROW");

Table ME 4.2. *Household Budget Shares*

	Base	Scenario 1	Scenario 2
Agriculture	.009		
Manufacturing			
Services			

 https://doi.org/10.1017/CBO9780511975004.012

Table ME 4.3. *Effects of a 50 Percent Increase in the World Price of Imported Agriculture (% change from base)*

	Consumer Price	Consumer Commodity Quantity	Household Domestic Quantity	Household Import Quantity	Production Quantity	Household Expenditure	Welfare $U.S. Million
GTAP variable name	*pp*	*qp*	*qpd*	*qpm*	*qo*	*yp*	EV
Agr.							
Mfg.							
Services							
Cobb-Douglas							
Agr.							
Mfg.							
Services							

7. Define your model experiment: 50 percent increase in *pm*("AGR","ROW")
   > Select Shock page table
   > Variable to shock, : "*pm*"
   > Elements to shock: "AGR,""ROW")
   > % change shock: 50 percent
   > Add to shock list
8. Change solution method and save the experiment
   > Select the "Solve" page tab
   > On the solve page, the solution method should be Johansen. If it is not, click on "Change." Select Johansen and then click on "OK"
   > On the solve page, check that the parameter file is "Default." If it is not, click on "Change," select "Default" from the box and click on "OK"
   > Click on "Save" and name the shock "PWAgr", describe it as 50 percent increase in the U.S. AGR import price
9. Solve the model
   > Click on "Solve"
   > OK
   > OK
10. Report model results in Table ME 4.3.
11. Report your results for new budget shares:
    > Select "View" from the upper menu bar
    > "Updated data" from the dropdown menu
    > GTAPView Output
    > NVPA (Row 16) this reports the updated commodity composition of household consumption
    > Select the dropdown menu for the box at top left, that says "None"
    > Select "COL", this reports each cell as a share of the column sum. These are the updated shares of each commodity in total private household spending. Report the data for the U.S. household in Table ME 4.2

12. Change your utility function parameters to replicate a Cobb-Douglas function (see Model Exercise 3 for instructions on how to change elasticity values and save a new parameter file.)
    > Set all INCPAR for the United States and rest-of-world equal to exactly one
    > Set all SUBPAR for the United States and rest-of-world equal to exactly zero
    > Save your new parameter file as "CobbDoug.prm"
13. View, and report in Table ME 4.1, your model's new parameter values for INCPAR and SUBPAR for the United States for scenario 2.
14. Save your experiment and rerun the model with the new parameter values
    > Select the "Solve" page tab
    > Click on the "Change" button next to "Parameter file: default" in the upper right corner
    > Select "CobbDoug" from the list
    > OK
    > Save the shock under its original name "PWAgr" (this saves the shock's linkage to the new parameter file)
    > Click on "Solve"
    > OK
    > OK
15. Report your new model results in Table ME 4.3.

Interpret Model Results

1. Compare the assumptions of the two utility functions in your CGE analysis about own-price elasticities of demand for agriculture (Table 4.3). How do you anticipate that the price increase will affect the quantity of household demand for AGR in both scenarios? Is this expectation consistent with the results of your general equilibrium model for both scenarios?
2. Compare the income effects implied by the utility functions and their parameter values, used in each scenario. Are the functions homothetic? For each utility function, describe whether each of the three goods are a necessity or a luxury, or if its demand quantity changes by the same proportion as income.
3. The elasticity of substitution is calculated as the percentage change in the quantity ratio of X to Y, relative to the percentage change in the price ratio of Y to X. (Hint, recall Text Box 2.1 on how to calculate the percentage change in a ratio.) Use model results from the experiment with the Cobb-Douglas utility function to calculate the elasticities of substitution (σ_C) between AGR and MFG and between AGR and SER. How would you characterize the relative curvature of indifference curves between these two pairs of goods?
4. How do changes in budget shares spent on agriculture compare in the two scenarios? Explain why these results, using your knowledge of the two different utility functions.

5. Most discussion of the world agricultural price shock focuses on consumers. How will the world price shock affect producers and the industrial composition of the U.S. economy? Can you explain why?
6. What is the Armington assumption? What is the import substitution elasticity (ESUBD) for AGR in your model? Given this assumption and parameter value, how do you expect U.S. demand quantities for AGR imports will respond when the world price increases by 50 percent? Is this expectation borne out by model results in both scenarios?
7. Using the model's results for the percentage changes in quantities of private household demand for imported (*qpm*) and domestic varieties (*qpm*), calculate households' elasticity of import substitution between the domestic and imported varieties for both scenarios. For scenario one, the percentage changes in the household's prices of domestic and imported varieties are 21.8 percent and 47.42 percent respectively. For scenario two, the respective percentage price changes are 21.29 percent and 47.43 percent. Are model results consistent with the elasticity you reported in question 6?
8. What does it mean when a country experiences a change in an equivalent variation measure of its welfare? In this experiment, is the United States better or worse off after the shock? Is this result sensitive to your choice of utility function?
9. Compare the effects of the two scenarios on household incomes (*yp*). Is this result sensitive to your choice of utility function?

Model Exercise 5: Food Fight: Agricultural Production Subsidies

Concepts: Production function, production subsidy, SUBTOTAL, factor substitution elasticity

Background

"Farm subsidies have outlived their usefulness," according to Robert Samuelson, the economic columnist for the *Washington Post* and *Newsweek*. In a recent column, "*The Endless Foodfight*," Samuelson argued that the original goals of farm subsidy programs have been met in the United States and other high-income countries. In the United States, agricultural subsidies were introduced in the depths of the Great Depression in order to raise incomes in rural areas and keep food prices low. Although there have been some modifications in the subsidy program over the years, the United States still provides production subsidies to its agricultural producers. Yet, conditions for farmers today are much different than they were in the 1930s. U.S. farm households now earn as much or more than the average urban U.S. household, and food accounts for only a small share of the budget of the average American family. Some people may advocate subsidies as a strategy to ensure that the United States maintains its ability to feed itself and avoids dependence on food imports. However, growing food imports by the United States largely reflect Americans' rising standard of living. Imports provide U.S. consumers with specialized agricultural and food products, and year-round access to seasonal produce.

Subsidies are costly and governments pay for them by levying taxes on other parts of the economy. Agricultural subsidies in the United States and other high-income countries have an additional cost – they jeopardize the success of global negotiations on trade liberalization, sponsored by the World Trade Organization (WTO). The countries' use of agricultural subsidies is thought to distort global markets by increasing their farm production and lowering world agricultural prices, thereby creating unfair competition for farmers in other countries. As long as high-income countries' agricultural subsidies remain in place, many of their trade partners are unwilling to lower their tariffs and allow greater entry to these and other exports from high-income countries.. The stalemate over agricultural subsidies contributed to the breakdown of the WTO negotiations in 2008.

If farm subsidies have outlived their usefulness and are increasingly costly, why do the United States and other high-income countries continue to use them? In this model exercise, you will conduct an experiment in which you eliminate all U.S. agricultural subsidies, which include production subsidies, intermediate input subsidies, and land use subsidies. You will use SUBTOTAL, a GTAP utility that allows you to decompose the results of each component of a multi-part experiment. Experiment results will illustrate the costs and benefits of agricultural subsidies in the United States, and provide some insight as to why it is so hard to eliminate them.

Experiment Design

What is the effect of an existing tax or tariff on an economy? One way to measure its effect is to remove it. The difference between an economy with and without the tax or subsidy provides a measurement of its economic impact.

In this exercise, you will calculate the cost of U.S. agricultural taxes and subsidies by removing them in three steps:

1. Eliminate all production taxes/subsidies;
2. Eliminate all land-base factor use subsidies; and
3. Eliminate all subsidies on the purchase of intermediate inputs by agricultural producers.

Instructions

1. Open the GTAP model with U.S. 3x3 database

This step opens the "version" of the GTAP model that uses the U.S. 3x3 database. You created this version of the model in exercise 1.

> Open "RUNGTAP"
> On the top menu bar, choose "Version"
> Change
> Select "US3x3"
> OK

2. Prepare your model to run an experiment – check closure
   > Select the "Closure" page tab.

Check that no closure changes are lingering there. The closure should end with "Rest Endogenous." If not, erase all text below that line.

3. Prepare your model to run an experiment – check shocks
   > Select "Shocks" page tab
   > Clear shock list
   This check ensures that there are no shocks lingering in your experiment file other than those you want to introduce.

Table ME 5.1. *Base and Updated Subsidy Rates*

	Base Rate	Updated Rate
Production subsidy		
rto("AGR", "USA")		
(negative value = tax)		
Land subsidy		
rtf("LAND", "AGR", "USA")		
(negative value = subsidy)		
Intermediate input subsidy on domestic input		
rtfi("AGR", "AGR", "USA")		
(negative value = subsidy)		
Intermediate subsidy on imported input		
rtfi("AGR", "AGR", "USA")		
(negative value = subsidy)		

4. Eliminate output subsidies in U.S. agriculture (*to*, "AGR", "USA")
   > Choose "Shocks" page tab
   > From the dropdown menu "Variable to shock," choose variable "*to*"
   > Select these elements of *to*: AGR and USA.
   > Note the initial *ad valorem* (AV) percent rate. This is the percentage production tax rate on U.S. agriculture. Write it down in Table ME 5.1.
   > Set a shock value of zero
   > Select "target rate = 0"
   > Click on "Add to shocks list"

5. Define output subsidy elimination as a "Subtotal" in your results
   > Click on "Define subtotal" button

This opens a dialogue box, shown in Figure ME 5.1, where you define each subtotal. You can wait and define all of your subtotals after you have finished setting up your experiment file, or you can define each subtotal after selecting each part of your shock, as we do in these instructions.

> Select variable: *to*
> Select elements: "AGR" and "USA"
> Click on "Add variable to the subtotal"
> OK
> Name it "AGR output subsidy"
> OK

6. Eliminate the factor use subsidy on land, *tf*, used in AGR by setting *tf* for elements Land, AGR, USA to zero (target rate = 0). Note the initial AV percent tax rate for *tf* and write it in Table ME 5.1.
7. Define the elimination of the land use subsidy as a subtotal in your results, named "Land subsidy"

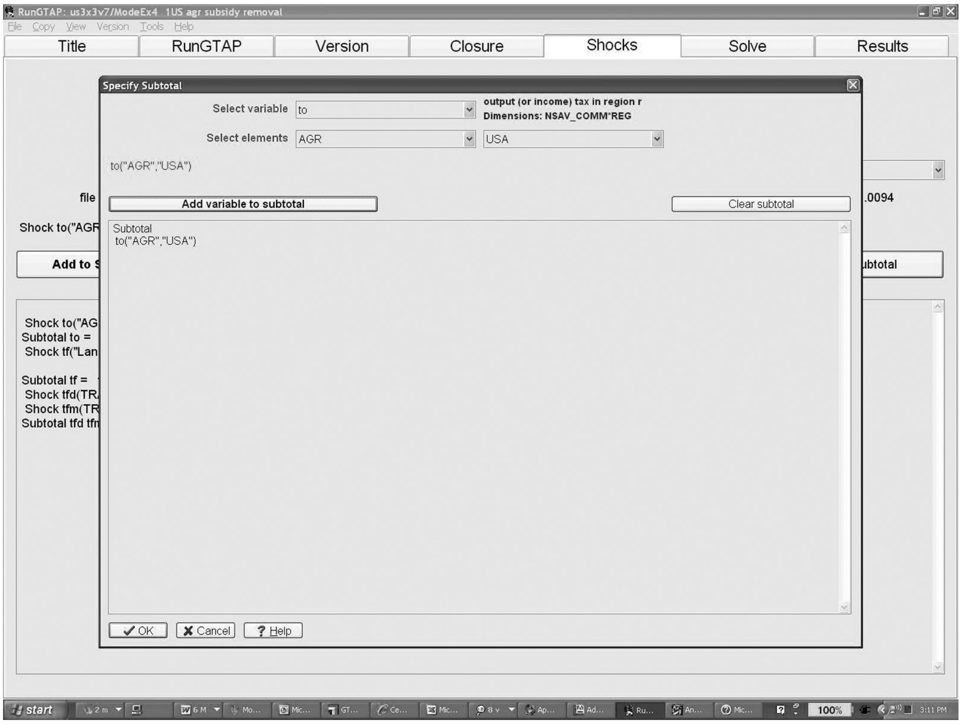


Figure ME 5.1. Define subtotals of a model shock

8. Eliminate input subsidies on domestically produced intermediate inputs, *tfd*, for elements All TRAD_COMM, AGR, USA by setting *tfd* to zero (target rate = 0).
9. Eliminate input subsidies on imported intermediate inputs, *tfm*, for elements All TRAD_COMM, AGR, USA by setting *tfm* to zero (target rate = 0)
10. Define the removal of both *tfd* and *tfm* as a subtotal in your results, named "Intermediate input subsidies"
11. Save the experiment
    > Select the "Solve" page tab
    > Check that the solution method is "Gragg 2-4-6." If it is not, click on "Change." Select Gragg and click on "OK"
    > Check that the parameter file is "Default." If it is not, click on "Change," select "Default" from the box and click on "OK"
    > Click on "Save" and name the shock "PWAgr", describe it as 50 percent increase in the U.S. AGR import price
12. Locate and view the base values for subsidies to U.S. agricultural firms on their purchases of domestic intermediate inputs
    > Click on "View" on the menu bar
    > Select "Base data" from the dropdown menu
    > Select tax rates from the dropdown menu
    > Select rTFD to display base *ad valorem* taxes to firms' purchases of domestic intermediate inputs

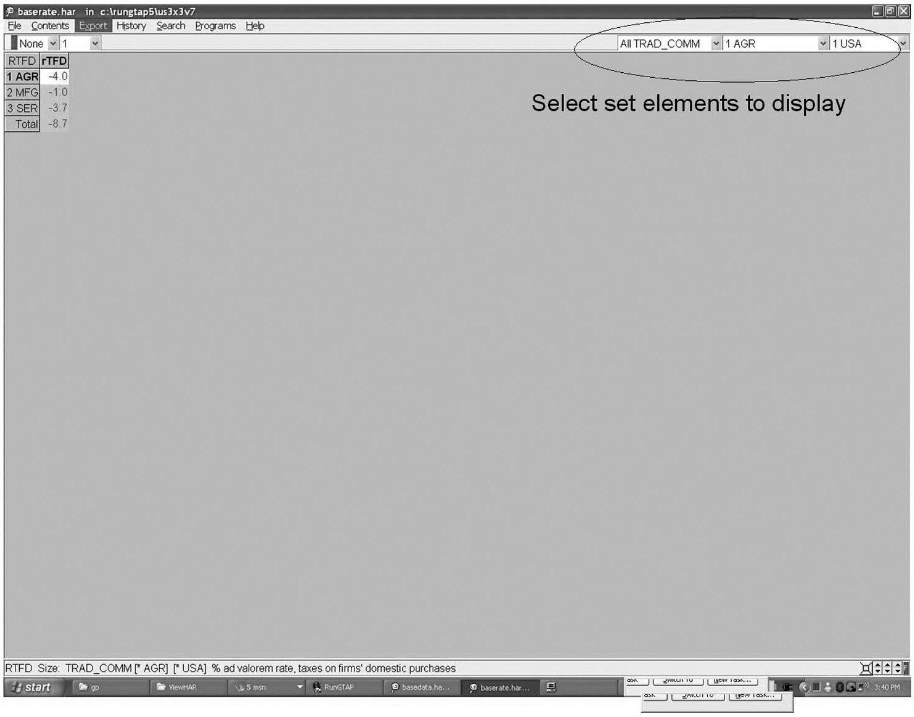


Figure ME 5.2. Select set elements to display for a tax with three dimensions tax

> Select elements: ALL_TRAD_COMM, AGR and USA in the upper right corner of the HAR file (Figure ME 5.2). In Table ME 5.1, report only the tax that is paid by agriculture on the agricultural input (rTFD("AGR","AGR", "USA")

13. Repeat these steps to report subsidies on U.S. AGR purchases of imported intermediate inputs (rTFI("AGR", "AGR, "USA") in Table ME 5.1.
14. Solve the model
    > Click on the "Solve" page tab
    > Click on the "Solve" button
    > OK
    > OK
15. Before viewing results, verify that your experiment has changed the tax rates as you expect by viewing the updated tax rates.
    > Click on "View" from the menu bar.
    > Select "Updated data" from the dropdown menu.
    > Select "Tax rates" from the dropdown menu.
    > Select "set elements" in the upper right corner that correspond to the dimensions for each tax listed in Table ME 5.1 Report the new tax rates in Table ME 5.1, for each of the four taxes in this experiment.
16. Report model results in Table ME 5.2 and in the first column of Table ME 5.3.

Table ME 5.2. *Effects of U.S. Agricultural Subsidy Elimination (% change from base)*

	Variable name in GTAP	Base ESUBVA Factor Substitution elasticity	ESUBVA = 2			
		Subtotals				
		Total	Production Tax/Subsidy Effect	Land Tax/Subsidy Effect	Intermediate Input Tax/ Subsidy Effect	TOTAL
Agricultural output quantity	*qo* (AGR,USA)					
Agricultural producer price	*ps*(AGR,USA)					
Land rent	*ps*(LAND,USA)					
Labor wage	*ps*(LABOR,USA)					
Capital rent	*ps*(CAPITAL,USA)					
Household consumption	*qp*[AGR,USA)					
Export quantity	*qxw*(AGR,USA)					

Table ME 5.3. *Change in Input-output Coefficients due to U.S. Agricultural Policy Reform (% change from base)*

Output and Inputs	Output and Input Quantities	Change in Input-Output Coefficients (*qfe-qo*) or (*qf-qo*)
AGR output (*qo*)	−0.37	Not applicable
Land (*qfe*)		
Labor(*qfe*)		
Capital(*qfe*)		
AGR intermediate (*qf*)		
MFG intermediate (*qf*)		
SER intermediate (*qf*)		

17. Follow the instructions in Model Exercise 3 to change the elasticity of factor substitution (ESUBVA) in all sectors to two. After changing your experiment to run with the new parameter file, re-solve the model and report only the total effects in Table ME 5.2.

Interpret Model Results

1. Draw a technology tree for U.S. agriculture in the U.S. 3x3 model. Identify the inputs in each nest and the values in your model for the elasticity parameters that govern substitutability within each nest and at the top level. Assume that σ_{AGG} equals zero.
2. Given the elasticity parameters in the AGR technology tree, explain how a change in relative input costs due to the policy reform could affect the ratios of intermediate and factor inputs used in U.S. agriculture.
3. In Table ME 5.3, calculate the percentage changes in input-output ratios for each input. Describe the changes in input intensities. Are these findings consistent with your depiction and discussion of the technology tree in the questions 1 and 2? Are they consistent with the changes in your factor price results reported in Table 5.2?
4. In the base elasticity case, how does the total effect of U.S. policy reform on AGR output compare with reforms of each separate component? If you were a policy maker, how might the availability of subtotaled results influence your thinking on the best way to phase in the reform program?
5. Compare the total effects of all reforms using the default versus the high factor substitution elasticity. Are they different? Why? Do you think that your model results are highly sensitive to the factor substitution value that you choose for your analysis?
6. Based on data in the U.S. structure table, in Chapter 3, what is the share of food in households' total expenditure on goods and services? Given that expenditure pattern, what might be the views of U.S. consumers on agricultural subsidy reform?

7. Farmland is mostly owned by farming households and land rents are an important source of farm household income. Based on the change in land rents in your results, how do you think rural U.S. households will view subsidy elimination?
8. In the our simple 3x3 model, land is employed only in agriculture while labor and capital are fully mobile across all three sectors; and all factors are fully employed. Given this assumption, why do you think there is no change in agricultural output in the subtotal in which only the land factor use subsidy is removed?
9. Based on your model results, what is your view of the concern of U.S. trade partners that U.S. farm programs increase output and exports, which depresses world prices?

Model Exercise 6: How Immigration can Raise Wages

Concepts: Factor endowment shocks, factors as complements and substitutes, factor substitution elasticity

Background

In 2008, there were 38 million immigrants living in the United States (U.S. Census Bureau, 2009). The United States is a nation of immigrants and historically has been a land of refuge and opportunity for foreigners. But with the number of immigrants now reaching more than 12 percent of the population, a contentious public debate has opened over the costs and benefits of the newcomers. On one hand, new workers add to the nation's stock of wealth, so the United States benefits from an increase in its productive capacity. On the other hand, new workers compete with native workers for jobs and may drive down wages – a key concern for U.S. labor. In addition, there are costs associated with the public services needed by immigrants that may not be sufficiently offset by the taxes that they pay.

The growing body of economic research on immigration offers conflicting results on their net impact on the U.S. economy and, in particular, its labor force. In a 2003 study, Dr. George Borjas concluded that immigration to the United States in the 1980s and 1990s reduced the average annual earnings of native-born workers by an estimated $1,700 or roughly 4 percent. Wages fell because employers can easily substitute immigrant labor for native U.S. workers in the same skill class. An immigrant auto mechanic, for example, can be substituted easily for a native-born auto mechanic. Dr. Borjas also accounted for the "cross-price effects" of immigration across skill classes. An increased number of auto mechanics, for example, leads to increased demand for native-born workers with complementary skills, such as dentists and teachers for the immigrants' children. But he found these cross-price wage benefits to be small. In a supply and demand framework, he concluded that the main effect of immigration has been to shift the labor *supply* curve outward for each skill class, causing the wages of native workers to fall.

Gianmarco Ottaviano and Giovanni Peri (2006) disagree with Borjas. In their study of immigration to the United States since the 1990s, they found that immigration has increased the average U.S. wage by 1.8 percent and the average wage of American-born workers by 2.7 percent. Two factors are at work. First, they argue that immigrant and native-born workers are relatively poor substitutes in the workplace. Even when they have similar educations, they tend to choose different occupations and have different types of skills. For example, an immigrant auto mechanic is a poor substitute for a native-born health technician. As a result, immigration mainly depresses the wages of earlier immigrants. Moreover, they found that cross-price effects are large, so that the increased number of immigrant auto workers has led to increased demand and higher wages for workers with complementary skills, like dentists and teachers. In a supply and demand framework, they argue that the dominant effect of immigration is to shift out the *demand* curve for native workers of all education levels.

A second factor, they argue, is that firms take advantage of the growing labor market by increasing their investment. In turn, new investment leads to increased demand for labor, a complementary factor to capital. In a supply and demand framework, an increase in the capital stock causes an outward shift in the demand for all labor types, which also helps boost wages.

Experiment Design

A key contribution made by the two studies was their authors' use of a general equilibrium framework to analyze the wage effects of immigration. Their studies took into account how wages in each type of labor market depended on its interaction with other types of workers and, in the Ottaviano and Peri study, with increased capital investment. This exercise is designed to help you to control and manipulate your CGE model in order to deconstruct and replicate the underlying assumptions made in these two influential and competing views on the economic effects of U.S. labor immigration.

In this model exercise, you will carry out a simulation of the general equilibrium effects of immigration on the United States. Your analysis is comparatively limited because your CGE model will have only two labor markets, skilled and unskilled labor, and will not differentiate between native and immigrant workers. In addition, your experiments rest on the simplifying assumption that labor migration occurs only in the unskilled labor category, although both skilled and unskilled workers immigrate to the United States. In the exercise, you will:

(1) Create a U.S. 3x3 model aggregation and model version that includes unskilled labor, skilled labor, and capital,
(2) Develop small theoretical models to illustrate the assumptions about labor supply and demand underlying your analysis.
(3) Carry out three experiments:

BORJAS simulates a 10 percent increase in the unskilled labor supply, assuming that factors are highly substitutable;
OTTA1 simulates the BORJAS experiment but assumes that factors are relatively complementary;
OTTA2 adds to OTTA1 a 6 percent increase in the U.S. capital stock.

Instructions

1. Open GTAPAgg7
2. From the menu bar, select "Read Aggregation Scheme from File."
   > Select the US3x3 aggregation file. This is a shortcut to creating a new 3x3 model, because regions and sectors in your database for this exercise remain the same as in the US3x3 database. If you did not create a U.S. 3x3 model, follow instructions in Model Exercise 1 to create a U.S. 3x3 database, and replicate the steps for "Define the country aggregation" and "Define the sector aggregation."
3. Define the factor aggregation.
   > From the menu bar, select "View/change factor aggregation"
   > In the table at the bottom of the page, right-click to remove all but three factor rows.
   > In the left column, type "UNSKILLED," "SKILLED," and "CAPITAL"
4. Define all factors as "mobile" in the column headed "ETRAE value or mobile"
5. Map factors into three-factor aggregation
   > Click on the "New factor" column of the mapping table in the upper right quadrant and pull down the mapping menu
   > Map: land to CAPITAL; unskilled labor to UNSKILLED, skilled labor to SKILLED LABOR; and capital and natural resources to CAPITAL
   > OK
6. Save your data aggregation file
   > From the menu bar, select on "Save aggregation scheme to file." (GTAP provides a default name, "gtp3_2.agg," which you can change to something descriptive, like "Imm.agg"
   > Save this aggregation file in the folder that you created for your research project
7. Create the aggregated database
   > From the menu bar, select "Create aggregated database." This creates a zip file with the aggregated database. Give it the same name as your aggregation scheme (e.g., Imm.zip), and save it in your project folder.
   > Close GTAPAgg7
   > Your database is now saved in zipped Header Array (HAR) files that are ready to use in your CGE model
8. Create a GTAP model version for the immigration exercise following the instructions in Model Exercise 1. Give your model version the same name as your aggregation scheme and database, (e.g. IMM).
9. The GTAP model will run a test simulation. It may fail if you are using the uncondensed version of the GTAP model. If so, click on "Tools" on the menu bar, and select "Run test simulation" from the dropdown box, and it will again run a test simulation.

10. Prepare your model to run an experiment – check closure
    > Select the "Closure" page tab
    Check that no closure changes are lingering there. The closure should end with "Rest Endogenous." If not, erase all text below that line.
11. Prepare your model to run an experiment – check shocks
    > Select "Shocks" page tab
    > Clear shock list
    > This check ensures that there are no shocks lingering in your experiment file other than those you want to introduce.
12. In the BORJAS scenario, you assume that factors can be substituted for each other relatively easily by changing the factor substitution elasticity to twelve for all industries (ESUBVA = 12). Follow instructions in Model Exercise 3 on how to change an elasticity parameter and save it in a new parameter file, named BORJAS.prm
13. Define the BORJAS model experiment:
    > Variable to shock: "*qo*"
    > Elements to shock: "UNSKILLED,""USA"
    > % change shock: 10 percent
    > Select: Add to shock list
14. Save the experiment file
    > Select the "Solve" page tab
    > Check that the solution method is Gragg 2-4-6. If it is not, click on "Change," select Gragg from the box and then click on "OK"
    > Change your parameter file by clicking on "Change" next to "Parameter file: default," and select your new parameter file name, Borjas.prm
    > OK (this closes your parameter file dialogue box)
    > Click on "Save experiment," name the shock BORJAS, describe and it as 10% increase in unskilled labor
15. Solve the model
    > Click on "Solve"
    > OK
    > OK
    Report your results in Table ME 6.1 and Table ME 6.2.
16. Create a new parameter file for OTTA1 and OTTA2 that describes factors as complementary by reducing the elasticities of substitution to:

    AGR = 0.2; MFG = 0.5; SER = 0.5 (the CGDS elasticity is irrelevant because this sector does not employ factors of production)
    Follow instructions in Model Exercise 3 on how to change an elasticity and save a new parameter file, named Otta.prm.

17. Create the OTTA1 experiment file
    > Adapt the BORJAS experiment file to use the Otta.prm parameter file. On the Solve page, click on the "change" button next to "Parameter file." Select Otta.prm.

Table ME 6.1. *Effects of 10 Percent Increase in the U.S. Supply of Unskilled Labor*

			Demand for Labor (*qfe*)		
Factor	Factor Price (*pfe*)	Industry	Unskilled	Skilled	Output (*qo*)
BORJAS – 10 percent increase in unskilled labor supply, high factor substitution					
Unskilled labor		Agriculture			
Skilled labor		Manufactures			
Capital		Services			
OTTA1 – 10 percent increase in unskilled labor supply, low factor substitution					
Unskilled labor		Agriculture			
Skilled labor		Manufactures			
Capital		Service			
OTTA2 – 10 percent increase in unkilled labor, 6 percent increase in capital, low factor substitution					
Unskilled labor		Agriculture			
Skilled labor		Manufactures			
Capital		Services			

> OK
> save the Borjas experiment as OTTA1
> Select the "Solve" button, solve the model, and report your results in Tables ME 6.1 and ME 6.2.

18. Define OTTA2 experiment by adding capital stock growth to the OTTA1 experiment:
    > Variable to shock: "*qo*"
    > Elements to shock: "CAPITAL," "USA"
    > % change shock: 6 percent
    > Select the "Solve" page tab
    > Save the model experiment and name it OTTA2
    > Select the "Solve" button, solve the model, and report your results in Tables ME 6.1 and ME 6.2.

Table ME 6.2. *Real GDP Effects of a 10 Percent Increase in U.S. Unskilled Labor Supply*

Scenario	% Change in Real GDP (*qgdp*)
BORJAS	
OTTA1	
OTTA2	

Interpret Model Results

1. Develop a theoretical model to describe the Borjas argument. Draw a graph for each labor market, identifying the supply and demand curves and the initial equilibrium quantities and wages. In the graph of the unskilled labor market, show the effects of unskilled labor immigration on wages and employment. Which curve shifts? In the graph of the skilled labor market, show the effect of the increased supply of unskilled workers. Which curve shifts? In which direction will it shift if the two types of labor are substitutes, as argued by Borjas?
2. How did you change the CGE model to represent factors as substitutes or as complements? What does a larger parameter value signify?
3. Are the wage results of the BORJAS experiment consistent with those of your theoretical model? Why are the effects of immigration on skilled wages and capital rents negative when factors are good substitutes?
4. Develop a theoretical model to describe the Ottaviano and Peri argument. Draw a graph for each labor market, identifying the supply and demand curves, and the initial equilibrium quantities and wages. In the graph of the unskilled labor market, show the effects of unskilled immigration on wages and employment. Which curve shifts? In the graph of the skilled labor market, show the effect of the increased supply of unskilled workers. Which curve shifts? In which direction will it shift if the two types of labor are relatively complementary, as argued by Ottaviano and Peri?
5. Are the wage results of the OTTA1 experiment consistent with those of your theoretical model? Why are the effects of immigration on skilled wages and capital rents positive when factors are relatively complementary?
6. Using your theoretical model describing the Ottaviano and Peri argument, add the effects of capital stock growth. Which curve shifts in each graph? In which direction will they shift if all factors relatively complementary, as argued by Ottaviano and Peri?
7. Are the wage results of the OTTA2 experiment consistent with those of your theoretical model? What happens in your model to the price of capital? Can you explain why?
8. How does the effect on agricultural output differ between the OTTA1 and OTTA2 scenarios. Can you explain why, using your knowledge of factor cost shares from the U.S. structure table?
9. Why does real GDP increase in all three scenarios? Why is real GDP growth higher in the BORJAS scenario compared to OTTA1?
10. What conclusions about modeling and the choice of elasticity parameters do you draw from your study of the two competing models of labor immigration?

Model Exercise 7: The Doha Development Agenda

Concepts: Import tariffs; export, production and input subsidies; SUBTOTAL and welfare decomposition

Background

The United States has participated in global trade negotiations under the General Agreement on Tariffs and Trade (GATT) – now named the World Trade Organization (WTO) – since shortly after the end of World War II. Consecutive rounds of trade negotiations have led to a reduction of global tariffs and other trade barriers, which has helped facilitate growth in global trade over the past six decades. Agriculture was generally excluded from the trade liberalization process until the Uruguay Round negotiations, which lasted from 1986–94. These talks placed limits on agricultural trade barriers and production and export subsidies. The WTO-sponsored trade negotiations continue today in the Doha Development Agenda Round, so-called because this round of negotiations was initiated in Doha, Qatar, in 2000 and is intended to benefit developing countries in particular.

There is much at stake for the global economy in the Doha Round, particularly for low-income countries, according to Kym Anderson and Will Martin, two prominent economists who studied the potential gains from the negotiations. Current trade barriers are high: high-income and low-income countries impose average tariffs of 16 percent and 18 percent tariff, respectively, on their agricultural imports (Table ME 7.1). Their average tariffs on manufactures average 1 percent and 8 percent, respectively. Agricultural subsidies continue to be provided, mostly by high-income countries.

To analyze the potential gains from eliminating these taxes and subsidies, Anderson and Martin used the World Bank LINKAGE model, a recursive dynamic global CGE model, to conduct their analysis (van der Mensbrugghe, 2005). The LINKAGE model is solved sequentially for a period of several years. The time path of solution values account for population growth over

Table ME 7.1. *World* ad valorem *Import Tariff Rates in Anderson and Martin (2005)*

	High-income Importers	Low-income Importers
Agriculture	16	18
Textiles	8	17
Other manufacturing	1	8
Total	3	10

Source: GTAP v6, 2001 database, as reported in Anderson and Martin.

the time period and the role of savings and investment in capital stock and productivity growth. Their version of the LINKAGE model uses the GTAP 2001 (v6) database.

Anderson and Martin concluded that the full removal of all import tariffs, export subsidies, and domestic agricultural subsidies would boost global welfare by nearly $300 billion annually. They then decomposed this welfare impact by high- versus low-income countries and by type of policy (Table ME 7.2). They concluded that agriculture is the key to the success of the negotiations because global liberalization of agricultural tariffs and subsidies would contribute nearly two-thirds of the potential global welfare gains, mostly through developed countries' reforms. Low-income countries also have a role in the reform process. Their removal of nonagricultural import tariffs would account for most of their contribution to world welfare gains from Doha. Anderson and Martin argue that it is important that the Doha Round address the full range of policies and industries because that approach offers possibilities for trade-offs, such as concessions on agricultural policies in exchange for concessions on nonagricultural policies.

Experiment Design

In this exercise, you will replicate Anderson and Martin's analysis of a global elimination of tariffs and agricultural subsidies using your U.S. 3x3 CGE model. Note some important differences between your model and theirs that make your results not directly comparable: (1) Their model uses a different, older version of the GTAP data, generally with higher tariffs and higher agricultural subsidy rates than in the v.7.0 data base used in this exercise. (2) Their model, LINKAGE, is a recursive dynamic CGE model that allows economies to grow in size, implying that their welfare effects of the same proportionate size to the economy will be larger than welfare results from your static CGE model. (3) The most important difference is that their model contains more country and industry disaggregation than the toy 3x3 CGE model used

Table ME 7.2. *Effects on Economic Welfare of Full Trade Liberalization from Different Groups of Countries and Products, 2015 (Total welfare effect = $U.S. 287 billion)*

	Agriculture	Textiles and Clothing	Other Manufactures	All Goods
High-income country policies	46	6	3	55
Low-income country policies	17	8	20	45
Total	63	14	23	100

Source: Anderson and Martin (2005).

in this exercise. The large aggregation of the rest-of-world economy in our toy CGE model results in very large terms-of-trade effects and substantial distortions remain in within-region trade in the rest-of-world. Both factors skew our welfare effects. Despite these model differences and caveats, this exercise remains useful for teaching you the modeling skills used to study multilateral trade liberalization, which has been an important application of CGE models.

In your experiment, you will use the GTAP SUBTOTAL facility (see directions in Model Exercise 5) to decompose global trade reform into four components:

1. U.S. Agricultural Policy Reform: eliminate U.S. agricultural tariffs, export subsidies, and production subsidies.
2. U.S. Nonagricultural Policy Reform: eliminate U.S. nonagricultural tariffs and export subsidies.
3. Rest-of-world (ROW) Agricultural Policy Reform: reduce ROW agricultural tariffs and export subsidies on trade with the U.S. by 50 percent, and eliminate agricultural production subsidies.
4. ROW Nonagricultural Policy Reform: reduce ROW nonagricultural tariffs and export subsidies on trade with the U.S. by 50 percent.

Instructions

1. Open the GTAP model with U.S. 3x3 database

This step opens the version of the GTAP model that uses the U.S. 3x3 database. You created this version of the model in Model Exercise 1.

> Open RunGTAP
> On the top menu bar, choose "Version"
> Change
> Select US3x3
> OK

2. Prepare your model to run an experiment – check closure
   > Select the "Closure" page tab.

Check that no closure changes are lingering there. The closure should end with "Rest Endogenous." If not, erase all text below that line.

3. Prepare your model to run an experiment – check shocks
   > Select "Shocks" page tab
   > Clear shock list

This check ensures that there are no shocks lingering in your experiment file other than those you want to introduce.

Table ME 7.3. *Base Tax Rates in U.S. 3x3 Model*

	United States (USA)			Rest-of-World (ROW)		
Tax Type	Agr.	Mfg.	Services	Agr.	Mfg.	Services
Subsidies on domestic intermediate inputs used in agricultural production (rTFD)						
Subsidies on imported intermediate inputs used in agricultural production (rTFI)						
Export subsidies (rTXS)						
Import tariffs (rTMS)						

Source: GTAP v.7.0.

4. Report selected base tax rates in Table ME 7.3.
   > Select "View" from the menu bar
   > Select "Base data" from the dropdown menu
   > Select "Tax rates" from the dropdown menu

For each tax, select the appropriate set elements to display from the boxes in the upper right corner. For export taxes and import tariffs, report the bilateral rates on U.S. and ROW exports to and imports from each other.

5. Define the first part of the experiment: U.S. Agricultural Policy Reform
   > Select the "Shocks" page tab
   > Set each of the variables listed below to a zero target rate (See directions on defining experiments in Model Exercise 3):
   tfd (tax on domestic intermediate inputs):
   elements All TRAD_COMM, "AGR", "USA"
   tfm (tax on imported intermediate inputs):
   elements All TRAD_COMM, "AGR", "USA"
   tms (import tariff): elements "AGR", "All REG," "USA"
   txs(export tax): elements: "AGR","USA," "All REG"
6. Define these shocks as the subtotal "US Ag Policy Reform" following the directions on defining subtotals in Model Exercise 5. Be careful to select the elements for each variable on the SubTotals page to match the set elements on the shocks page.
7. Define the second part of the experiment: U.S. Nonagricultural Policy Reform
   > Set each of the variables listed below to a zero target rate:
   tms (import tariff): elements("MFG","ROW","USA")
   txs (export tax): elements("MFG","USA","ROW")

Because tariffs and taxes on trade in services are zero in the GTAP database, we do not need to remove them in our experiment.

8. Define the two shocks in the step above as the subtotal "US NonAg Policy Reform."
9. Define the third part of the experiment: Rest-of-World Agricultural Policy Reform
   > Select the "Shocks" page tab
   > Set each of the variables listed below to a zero target rate:

   tfd (tax on domestic intermediate inputs):
   elements All TRAD_COMM, "AGR","ROW"
   tfm (tax on imported intermediate inputs):
   elements All TRAD_COMM, "AGR", "ROW"

   > Set each of the variables listed below to minus 50 percent change in the tax rates

   tms (import tariff): elements "AGR", All "USA","ROW"
   txs(export taxes): elements: "AGR","ROW", "USA"
10. Define these shocks as the subtotal "ROW Ag Policy Reform"
11. Define the fourth part of the experiment: ROW Nonagricultural Policy Reform
    > Set each of the variables listed below to minus 50 percent change in the tax rates.

    tms (import tariff): elements("MFG","USA","ROW")
    txs (export taxes): elements("MFG","USA","ROW")
    Because tariffs and taxes on trade in services are zero in the GTAP database, we do not need to remove them in our experiment.
12. Define these shocks as the subtotal "ROW NonAg Policy Reform."
13. Check that your shock page looks like Figure ME 7.1.
14. Save the experiment file
    > Select the "Solve" page tab
    > Check that the solution method is Gragg 2-4-6. If it is not, click on "Change," select Gragg from the box and then click on "OK"
    > Check that the parameter file is "Default". If it is not, click on "Change," select default.prm from the box and click OK.
    > Click on "Save experiment," name the shock DOHA, and describe it as Doha Development Agenda
15. Solve the model
    > Select "Solve" page tab
    > Save experiment
    > Name the experiment "Doha"
    > >OK
    > Solve
16. After running the experiment, check that the updated tax rates are what you expect them to be. This is a good habit to practice, especially when carrying

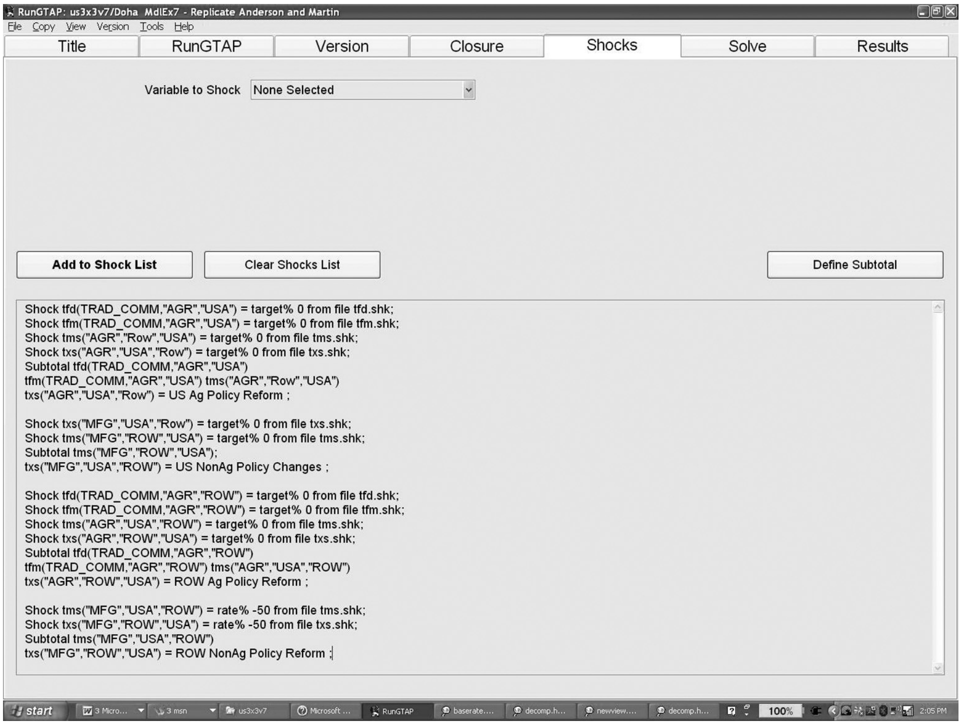


Figure ME 7.1. Shocks page for Doha Development Agenda experiment

out complex tax experiments such as this. For example, check that the input subsidies used by the agricultural sectors in the U.S. and rest-of-world are now zero:

> Select "View" from the menu bar
> Updated data (from the dropdown menu)
> Tax rates (from the dropdown menu)
> rTFD – the *ad valorem* tax rate on firms' domestic purchases
> Select set elements to display (in the upper right corner of the tax display page):
ALL TRAD_COMM, AGR, ALL REG. All should have a value of zero.
> Select and view each of the taxes that you have changed in this experiment.

17. From the results page, report model results for the equivalent variation welfare effect, EV, in Table ME 7.4.
18. Report the decomposition of the total welfare effect, reported in the GTAP welfare decomposition utility in Table ME 7.5.
> Select "View" from the menu bar
> Select "Updated data" from the dropdown menu
> Select "Welfare decomposition"
> Click on "EV decomposition summary" (in row 1)
19. From the results page, report changes in export quantities, *qxw*, in Table ME 7.6.

Table ME 7.4. *Welfare Effects of Trade Liberalizationby Region and by Policy, $U.S. Millions*

	Total	U.S. Agricultural Policy Reform	U.S. Nonagricultural Policy Reform	Rest-of-World Agricultural Policy Reform	Rest-of-World Non-agricultural Policy Reform
United States					
ROW					
World					

Note: Welfare is an equivalent variation measure.
Source: GTAP model, GTAP v.7.0 U.S. 3x3 database.

Interpret Model Results

1. Is the total world welfare effect of global trade reforms positive or negative? Explain what a change in the equivalent variation measure of welfare means.
2. Which elements of the global reform contribute most to increasing or decreasing global welfare? Based on these findings, what advice would you give to policy makers on the best win-win strategy for participants in this negotiation?
3. Comment on the changes in export quantities. Can you explain these changes based on the initial import tariffs in your model?
4. Consider your welfare decomposition results. The allocative efficiency effect measures the efficiency gains to each economy when distorting taxes are reduced or removed. How important are these efficiency gains to both regions?
5. Consider your welfare decomposition results. What does the terms of trade effect measure? How important is this effect in your model results? Explain why the terms of trade gains and losses to each region offset each other in your 3x3 model.
6. Which elasticity parameter in your CGE model most directly influences the terms of trade results in your model? Explain why.

Table ME 7.5. *Decomposition of the Total Welfare Effect, $U.S. Millions*

	Total	Allocative Efficiency	Terms of Trade in Goods and Services	Terms of Trade in Savings-Investment
United States				
ROW				
World				

Note: Welfare is an equivalent variation measure.
Source: GTAP model, GTAP v.7.0 U.S. 3x3 database.

Table ME 7.6. *Effect of Trade Liberalization on Exports (% change from base)*

	U.S.	Rest-of-World
Agriculture (*qxw*)		
Manufacturing (*qxw*)		
Services (*qxw*)		

7. How does your total world welfare result compare with that of Anderson and Martin? What are the differences between your CGE model and theirs that might explain some of the differences in your results?
8. Compare your tariff data with that of Anderson and Martin. How do your tariff data and your model experiment differ from theirs? Explain how these might lead to differences in your model results.

Model Exercise 8: The Marginal Welfare Burden of the U.S. Tax System

Concepts: Taxation; direct, excess and marginal welfare burden of taxes, welfare decomposition, systematic sensitivity analysis

Background

The United States tax system was the subject of some of the earliest applications of CGE models. An influential contributor to this body of research was the economist team of Charles Ballard, John Shoven, and John Whalley. They developed a recursive dynamic CGE model that supported several analyses of U.S. taxes, including Ballard, Shoven, and Whalley (1985). Their CGE model of the United States was based on a 1973 database with nineteen industries, twelve household types and eight types of taxes. Their model solved first for a baseline time path of the economy's growth. Their experiments then introduced changes in U.S. tax rates. The results of their model experiments plotted alternative time paths of U.S. economic growth, with and without the tax changes.

In their 1985 study, the team used their CGE model to analyze the combined marginal excess burden – the deadweight efficiency losses – of all taxes in the U.S. economy. The marginal tax rates in their model, reported as the average across industries and commodities, are presented in Table ME 8.1. Their tax rates are reported as the rate paid on net-of-tax income or net-of-tax expenditure. For example, if the tax paid on \$1 of dividend income was 50 cents, then the individual would retain fifty cents in net-of-tax income. In this case, the tax rate would be 100 percent of net income (which is close to the rate of .97 reported in Ballard, et al.'s model).

Their experiments were a 1 percent increase in every tax rate in the U.S. economy simultaneously and a 1 percent increase in each tax rate at a time. In this dynamic model, tax changes influenced households' savings rates and therefore the accumulation of capital and investment in the economy. Tax changes also influenced households' decision about how many hours to work. And, as in our standard, static CGE model, taxes led consumers and producers to change the quantities that they produced and consumed as taxes changed relative prices of goods and services. Together, changes in investment and the supply of labor, and resource reallocation, altered the growth path of the economy. The authors also explored the sensitivity of their results to alternative elasticity parameter values for labor supply and household savings.

The team found that, depending on the elasticities, the marginal excess burden of the U.S. tax system ranged between seventeen cents and fifty-six cents per dollar of additional tax revenue (Table ME 8.2). This meant

Table ME 8.1. *Level and Dispersion of Tax Rates in the Model*

	Average Marginal Tax Rates
Capital and property taxes	.97
Labor (factor use) taxes	.101
Consumer sales taxes	.067
Output and excise taxes	.008
Motor vehicle taxes	.052
Personal income taxes	.239

Source: Ballard, Shoven, and Whalley, 1985.

Table ME 8.2. *Marginal Excess Burden per Additional Dollar of Revenue for U.S. Taxes*

	Saving Elasticity		
Labor supply elasticity	0.0	0.4	0.8
0.0	.170	.206	.238
0.15	.274	.332	.383
0.30	.391	.477	.559

Source: Ballard, Shoven, and Whalley, 1985.

that government projects to be funded by the tax increase would have had to yield benefits at least 17 percent greater than the amount of the additional tax revenue. After changing one tax at a time, they concluded that the consumer sales tax was the most distorting of the U.S. taxes (Table ME 8.3).

Based on their findings, Ballard, et al., argued that plans for public spending on projects or on income transfers, such as welfare payments, needed to take into account the efficiency losses incurred by raising additional tax revenue. They also argued that the large marginal excess burden of additional

Table ME 8.3. *Marginal Excess Burden per Dollar of Additional Revenue from Specific Portions of the Tax System*

Uncompensated saving elasticity	0.0	0.4	0.0	0.4
Uncompensated labor supply elasticity	0.0	0.0	.15	.15
All taxes	.17	.206	.274	.332
Capital taxes	.181	.379	.217	.463
Labor taxes	.121	.112	.234	.230
Consumer sales tax	.256	.251	.384	.388
Sales tax on commodities other than alcohol, tobacco, gas,	.035	.026	.119	.115
Income taxes	.163	.179	.282	.314
Production taxes	.147	.163	.248	.279

Source: Ballard, Shoven, and Whalley, 1985.

taxes conversely offered opportunities, because there could be large marginal efficiency gains from small reforms in taxes.

Experiment Design

In this exercise, you will replicate the Ballard, Shoven, and Whaley (1985) study using the GTAP model with the U.S. 3x3 database. There are differences between your models that are likely to lead to differences in your results. Your model has a 2004 database and you will be asked to see how its tax rates differ from the 1973 rates described in the Ballard, et al., analysis. Note that almost all tax rates reported in your CGE model are calculated gross of tax, so they will be lower. That is, if the tax paid on $1 of dividend income was 50 cents, then the tax rate would be 50 percent of gross income. Your model is aggregated to three industries and a single household so there is less scope for distortions in the relative prices of goods, and the efficiency losses from tax increases could therefore be smaller. Also, Ballard, et al., use a recursive dynamic CGE model while yours is a static CGE model with a fixed supply of capital and labor. Therefore, by assumption, your model will not account for taxes' effects on the supply of savings and investment. In addition, income taxes influence labor supply in their model, whereas the labor supply is fixed in your model. On the other hand, your model has capabilities that theirs did not. Because it is a multicountry model, your measure of the welfare effects of tax reform includes not only the excess burden of taxes but also their terms of trade effects. Also, the welfare decomposition utility of the GTAP model allows you to decompose the contributions of each type of tax to the total excess burden, instead of running separate experiments. Finally, the systematic sensitivity analysis utility allows you to describe confidence intervals around your results as you test for sensitivity to one parameter, the factor substitution elasticity.

In this exercise, you will:

1. Change selected elasticity parameters.
2. Define and run an experiment that increases all U.S. taxes by 1 percent.
3. Use the GTAP welfare decomposition facility to decompose the contribution of each tax to the excess burden of the tax increase.
4. Carry out a systematic analysis of the sensitivity of welfare results to alternative assumptions about the factor substitution elasticity.

Instructions

1. Open GTAP model with U.S. 3x3 database
   This step opens the version of the GTAP model that uses the U.S. 3x3 database. You created this version of the model in exercise 1.

> Open RUNGTAP
> On the top menu bar, choose "Version"
> Change
> Select "US3x3"
> OK

2. Prepare your model to run an experiment – check closure
   > Select the "Closure" page tab.
   Check that no closure changes are lingering there. The closure should end with "Rest Endogenous." If not, erase all text below that line.
3. Prepare your model to run an experiment – check shocks
   > Select "Shocks" page tab
   > Clear shock list
   This check ensures that there are no shocks lingering in your experiment file other than those you want to introduce.
4. Change these elasticity parameters and save a new parameter file (see instructions in Model Exercise 3):
   > ESUBVA (factor substitution elasticity) = 2 in all production activities
   > ESUBD (demand substitution between imported and domestic) = 6 for all commodities
   > ESUBM (demand substitution among imported varieties) = 10 for all commodities
   > RORFLEX parameters = 1 (this reduces the effect of investment changes on the rate of return to investment)
   > Save the new parameter file and name it "Ballard.prm"
5. Define your experiment:
   > Select, sequentially, each of these tax rates: *tf*, *tfd*, *tfm*, *tgd*, *tgm*, *to*, *tm*, *tp*, *tx*
   > Select all elements for each tax for the U. S. region only
   > Define shock value for each tax as 1
   > Define type of shock as "% change rate"
6. Your experiment page should look like Figure ME 8.1.
7. Save the experiment file
   > Select the "Solve" page tab
   > Check that the solution method is Gragg 2-4-6. If it is not, click on "Change," select Gragg from the box and then click on "OK"
   > Change your parameter file by clicking on "Change" next to "Parameter file: default," and select your new parameter file name, Ballard.prm
   > OK (this closes your parameter file dialogue box)
   > Click on "Save experiment," name the shock "Ballard," describe and it as 1% increase in all taxes
8. Solve the model
   > Click on Solve
   > OK
   > OK

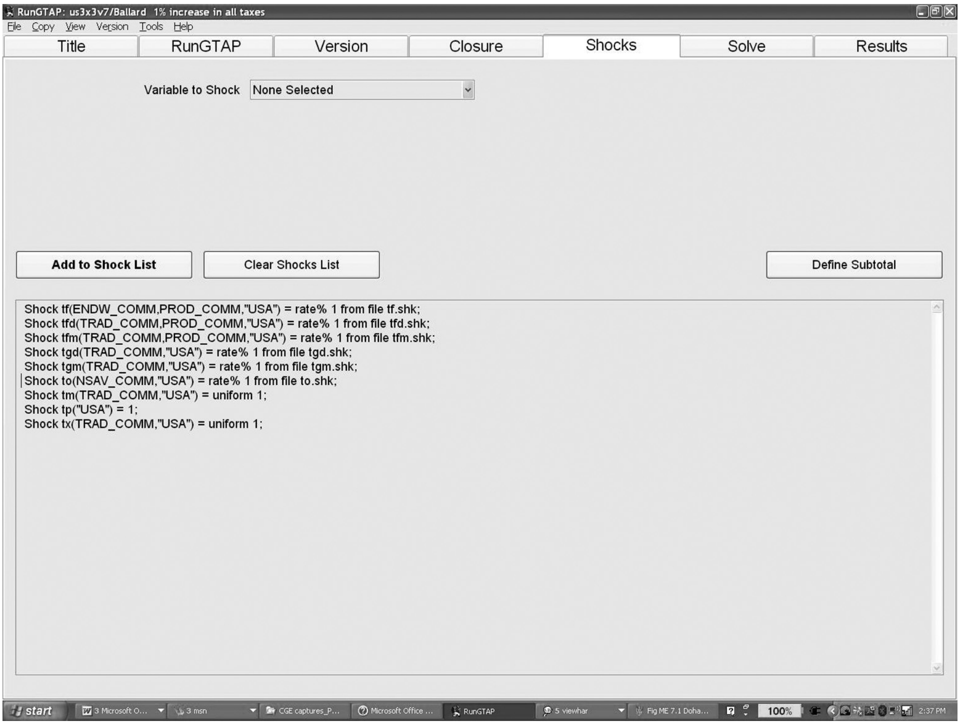


Figure ME 8.1. Shocks page in marginal welfare burden experiment

9. Report results from the welfare decomposition utility in Tables 8.4 and 8.5.
   > Select "View" from the menu bar
   > Updated data
   > Welfare decomposition
   > Select "EV Decomposition Summary" (row 1) for Table ME 8.4 results
   > Return to main menu of decomposition by double-clicking on data anywhere in the matrix
   > Select "Allocative efficiency by tax type" (row 3) for Table ME 8.5 results
10. Calculate the change in total government tax revenue by comparing the pre- and post-experiment tax revenues. Find the base tax revenue value by selecting from the top menu bar:
   > Select "View" from the menu bar
   > Base data
   > GtapView Output
   > GDPSCR (GDP from the income sources side)

Table ME 8.4. *Welfare Effects of a 1 Percent Increase in U.S. Taxes ($U.S. Million)*

Allocative efficiency	Endowment	Technology	Population	Terms of trade in goods and services	Terms of trade in investment-savings	Preference	Total welfare cost	Change in government tax revenue	Welfare cost per dollar of revenue

Source: GTAP model, U.S. 3x3 v.7.0 database.

Table ME 8.5. *Welfare Decomposition of the Allocative Efficiency Effect ($U.S. Million)*

Tax Type	Welfare Cost
Factor tax (pfattax)	
Production tax (prodtax)	
Input tax (inputtax)	
Consumption tax (contax)	
Government tax (govtax)	
Export tax (etax)	
Import tax (mtax)	
Total	

Source: GTAP model, U.S. 3x3 v.7.0 database. Experiment is a 1 percent increase in all U.S. taxes.

> Report NETAXES (total tax revenue) for the U.S.
Find updated tax revenue data by repeating these steps, choosing "Updated data" instead of "base data":

a Base government tax revenue ($ U.S. millions)

____

b Updated government tax revenue ($ U.S. million)

____

c Change in government tax revenue ($ U.S. million)

____

11. Calculate the marginal welfare burden of the U.S. tax system. It is the welfare cost per additional dollar of tax revenue:

Total welfare cost/Change in government tax revenue * 100 = Marginal welfare burden

12. Carry out a systematic sensitivity analysis (SSA) of model results to changes in the elasticity of factor substitution (ESUBVA) parameter. Follow the instructions in Model Exercise 3, and use the information below as your inputs to the SSA utility.
> Parameter to vary: ESUBVA
> Elements to vary: ALL PROD_COMM
> Percent variation: 100 (the sensitivity analysis will vary the ESUBVA elasticity parameter value between close to zero and two times the base parameter value, or 4)
> Type of variation: Percent (this is the default choice)
> Type of distribution: triangular (it is similar to a bell curve distribution and is the default choice)
> Name and save your two result files from the SSA by replacing the star in the file name with "Ballard" – without the quotes.
> Open and view the files with the sensitivity analysis results.

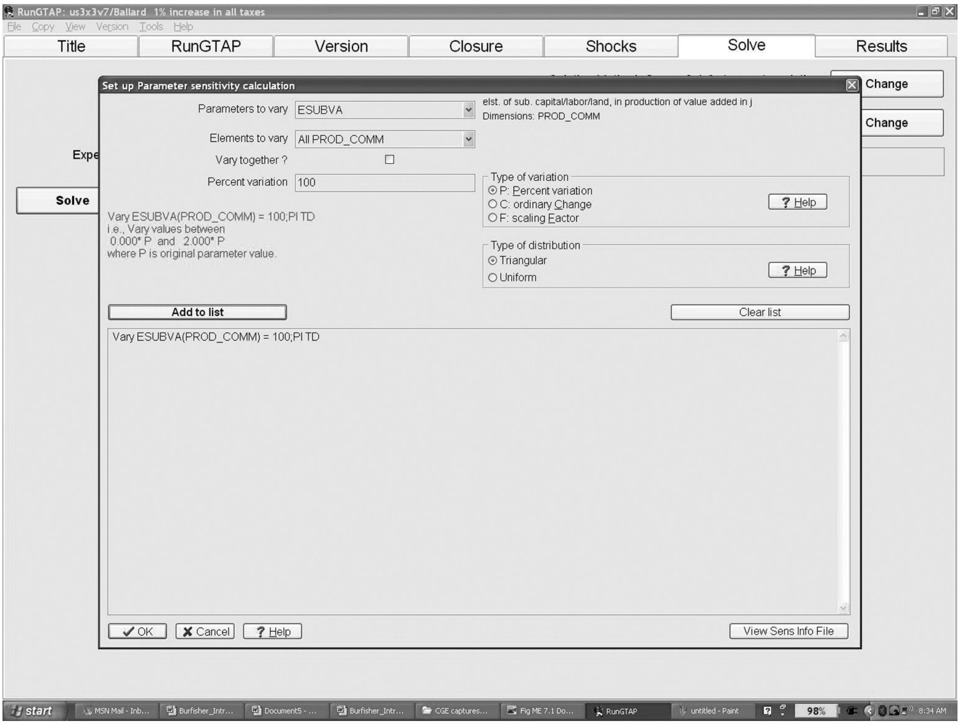


Figure ME 8.2. Systematic sensitivity analysis

13. Report results from the ViewSol file for U.S. equivalent variation measure of welfare (EV):

    EV ________________
    Mean ________________
    Standard deviation _______

Interpret Model Results

1. Based on your results, what is the direct burden of the marginal tax increase? What is its excess burden (allocative inefficiency)?
2. According to results reported in Table 8.5, which tax has the largest marginal welfare effect? The smallest? Use data from the U.S. 3x3 structure table and your knowledge of the excess burden of taxes to explain your results for these two taxes.
3. Based on your results in Table 8.4, what is the marginal welfare cost per dollar of additional revenue from the U.S. tax system? Explain how you would use this number to advise policy makers considering a tax increase to fund a government project.
4. How important is the terms of trade gain in goods and services in the welfare results? Explain what a change in the terms of trade means. Why is it included in the welfare measure?

5. How does your finding on the marginal welfare cost per dollar of marginal revenue compare with the findings of Ballard, Shoven, and Whalley? What are some of the differences between your CGE models that might account for differences in results?
6. Using the U.S. 3x3 structure table in Chapter 3, compare your tax rates with those of Ballard, Shoven, and Whalley. Although your tax categorization differs somewhat from that of Ballard, Shoven, and Whalley, how do you think the differences in your data might account for different model results?
7. Using the results of the systematic sensitivity analysis on the elasticity of factor substitution (ESUBVA) and Chebyshev's theorem (see Model Exercise 3), define the range of value for the U.S. equivalent variation welfare effect in which you have 75 percent confidence and 95 percent confidence. Based on your sensitivity analysis of the elasticity, do you think that the equivalent variation welfare result is a robust finding?

Model Exercise 9: Successful Quitters – The Economic Effects of Growing Antismoking Attitudes

Concepts: Changing consumer preferences, macroeconomic projections, systematic sensitivity analysis

Background

Cigarette smoking can have serious health consequences, not only for smokers but also for those around them who breathe in their second-hand smoke. As more becomes known about the negative effects of cigarettes on health, consumer attitudes toward smoking – at least in some countries – have begun to change. The days of glamorous movie stars puffing on cigarettes on the silver screen are long gone. Instead, smoking is increasingly viewed unfavorably, and there is growing social acceptance of (and even demands for) bans on smoking in public places like offices, restaurants, and airplanes.

Globally, cigarette consumption has declined since the 1990s, but this broad trend masks differences among categories of countries, according to Goel and Nelson (2004). Their international comparison of smoking trends found that declining cigarette consumption is correlated with a country's stage of development. Approximately one-half of the high and upper middle-income countries in their data set witnessed a decline in per capita cigarette consumption in excess of 20 percent since the 1990s. In contrast, cigarette consumption actually increased over that period in half of the low-income countries in their study. Goel and Nelson suggest a number of reasons why a country's stage of development may affect its national smoking habits. For example, wealthier nations have better resources to monitor and control tobacco use, and a more educated population might be more aware of the health risks posed by smoking. But the researchers also found many exceptions to this broad relationship between smoking and income. These variations probably reflect the significant differences across countries in antismoking policies, such as taxes and regulations on trade and advertising.

Changes in consumer attitudes toward particular products can have important consequences for an industry. Sometimes changing attitudes lead to a boom in consumer demand, such as the new popularity of organic foods. In other cases, consumers develop aversions, such as the avoidance of conflict diamonds because their proceeds may fund wars. When the affected industries are important in a national economy, changes in consumer preferences can also have significant economywide effects.

In this exercise, you will create a 3x3 database with a tobacco sector, to explore the effects of changing consumer attitudes about smoking as incomes grow. You will start by studying your SAM database, to understand the role of tobacco in the U.S. and ROW economies. Next, you will develop a model experiment that describes long-term income growth by incorporating macroprojections for endowment growth and productivity effects, following the methodology used by Arndt, et al. (1997). Then, you will simulate the effects of projected economic growth when (1) global consumer preferences remain unchanged, and (2) consumers in the rest-of-world become more averse to tobacco products as their incomes grow. You will select and examine model results that answer the question, "How will consumer attitudes toward smoking affect countries' tobacco industries and their national economies as global incomes rise over the next decade?" Given the uncertainty about the extent to which income growth may change consumer preferences, you will use the systematic sensitivity analysis utility with respect to the income parameter, INCPAR. This will allow you to describe model outcomes in terms of means, distributions, and confidence intervals.

Experiment Design

Your static CGE model describes an economy in equilibrium before and after a model shock. Defining 10 year macroprojections as a model shock essentially imposes a new macroeconomic equilibrium with higher levels of capital, labor, and productivity. Your model then solves for the consistent microeconomic structure. For example, if the economy's total capital stock (a macroeconomic parameter) is assumed to increase by 10 percent, your model results describe the microeconomic changes in capital stock in each industry, industry output, commodity demand, and so forth.

To define your experiment, you will need to know the *cumulative* growth in endowments and productivity over your projection time period of 2005–14. (We begin with 2005 because 2004 is the base year for our data.) For example, consider a three period case, in which capital stock growth between periods one and two (k_1) is 2.5 percent, and growth between periods two and three (k_2) is 1.3 percent. Assuming that the initial capital stock (K) in period one is fifty, we calculate the cumulative growth between periods one and three in two steps:

1. Calculate the size of the capital stock in the final period: $K * (1 + k_1/100) * (1 + k_2/100)$

$$50 * 1.025 * 1.013 = 51.92$$

2. Calculate the cumulative growth rate as the percent change between the base capital stock and the capital stock in the final period:

$$(51.92 - 50)/50 = .0384 * 100 = 3.84$$

Table ME 9.1. *Annual Growth Rates in Factor Endowments and Productivity*

	Base Quantity	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Labor force Cumulative											
USA	1	0.4	1.6	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6
ROW	1	1.6	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4
Capital stock											
USA	1	4.1	4	4	3.9	3.9	3.8	3.8	3.7	3.7	3.7
ROW	1	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8
Total factor productivity											
USA	1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
ROW	1	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4

Notes: We assume that Walmsley's data for North America describes growth rates for the United States and that the average of growth rates for all other regions describe growth rates for ROW. Productivity projections for the United States extrapolate the 2007–08 multifactor productivity growth reported for the U.S. by the BLS and ROW productivity growth is assumed to be twice the level of the United States.
Source: Endowment data from Walmsley (2006); productivity data from Bureau of Labor Statistics (2009) and author calculations.

Table ME 9.1 presents macroprojections reported in the literature. Use these data to calculate the cumulative growth rates in endowments and productivity for the U.S. and ROW during 2005–14, rounding up your answers to whole numbers. Report the cumulative growth rates Table ME 9.2. One answer is provided to help you to check your work. You will use the cumulative growth rates to define your model shock.

In the first scenario, you will run the growth experiment using the default parameters in the CDE consumer utility function assumed in the GTAP model. In this scenario, there are no changes in attitudes about smoking as incomes grow.

In the second scenario, you will assume that consumers in the rest-of-world develop stronger antismoking attitudes as their incomes grow. You describe this change in preferences in the GTAP model by reducing the value of the INCPAR parameter, which is similar to, but not exactly the same as, the income elasticity of demand. When this parameter is reduced, any given

Table ME 9.2. *Cumulative Growth Rates*

	Labor force
USA	16
ROW	
	Capital stock
USA	
ROW	
	TFP
USA	
ROW	

percentage increase in income will result in a smaller increase in consumers' tobacco purchases. You will reduce INCPAR to a value that reduces the quantity of tobacco demanded in ROW by about 20 percent compared to current preferences. This is about the same quantity reduction experienced in developed countries during the 1990s.

There are some limitations to our analysis. One is our simplifying assumption that "ROW" preferences describe developing countries. Our 3x3 aggregation scheme includes all countries except the United States, so at least some countries included in ROW have already experienced changes in attitudes about smoking. A second limitation is that the GTAP database combines beverages with tobacco, so demand and production of "tobacco" in our model is not completely accurate. Third, it is difficult to predict how economic growth will affect consumer preferences because these are not always fully explained by economic forces. The systematic sensitivity analysis with respect to the INCPAR parameter allows us to characterize the preference change as a range instead of a specific value, and to present our model results in terms of means and distributions.

Instructions

1. Open GTAPAgg7
2. From the menu bar, select "Read Aggregation Scheme from File."
   > Select the U.S. 3x3 aggregation file (This is a shortcut to creating a new 3x3 model, because regions and factors in your database for this exercise remain the same as in the U.S. 3x3 database. If you did not create a U.S. 3x3 model, follow instructions in Model Exercise 1 to create a U.S. 3x3 database, and replicate the steps for "Define the country aggregation" and "Define the factor aggregation.")
3. Define the sector aggregation.
   > From the menu bar, select "View/change sectoral aggregation."
   > Create these three sectors:

TOB – "tobacco"	comprised of sector 26 b_t
AGRMFG – "AGR and MFG"	comprised of sectors 1–25, 27–42
SER – "Services"	comprised of 43–57

   > OK (this saves your new sector aggregation)
4. Save your data aggregation file
   > From the menu bar, select on "Save aggregation scheme to file." (GTAP provides a default name, "gtpXX.agg," which you can change to something descriptive, like "TOB.agg.")
   > Save this aggregation file in the folder that you created for your research project.

Table ME 9.3. *Role of Tobacco in Economywide Production*

	USA	ROW
Share of tobacco in total activity output		

Source: GTAP v.7.0 3x3 tobacco database.

5. Create the aggregated database.
   > From the menu bar, select "Create aggregated database." This creates a zip file with the aggregated database. Give it the same name as your aggregation scheme, for example TOB.zip, and save it in your project folder.
   Your database is now saved in zipped Header Array (HAR) files that are ready to use in your CGE model.
6. Explore the SAM to learn about the role of the tobacco sector in the economy
   > Still in GTAPAgg7, click on "View output files" in the menu bar
   > Select "ASAM" (the top row)
   > On the upper right side, choose these set elements to display the ROW SAM:

   ALL SAMAC, ALL SAMAC, ROW
   Calculate the share of the gross value of tobacco output in total activity output in ROW, and report it in Table ME 9.3.
7. Repeat these steps to calculate and report the share of tobacco in activity output in the United States, after changing the set elements to display to:

   ALLSAMAC   ALLSAMAC   USA

8. Create a GTAP model version for the antismoking exercise following the instructions in Model Exercise 1. Give your model version the same name as your aggregation scheme and database, TOB.
9. The GTAP model will run a test simulation. It may fail if you are using the uncondensed version of the GTAP model. If so, click on tools on the menu bar, and select "Run test simulation" from the dropdown box, and it will again run a test simulation.
10. Prepare your model to run an experiment – check closure
    > Select the "Closure" page tab
    Check that no closure changes are lingering there. The closure should end with "Rest Endogenous." If not, erase all text below that line.
11. Prepare your model to run an experiment – check shocks
    > Select "Shocks" page tab
    > Clear shock list
    This check ensures that there are no shocks lingering in your experiment file other than those you want to introduce.
12. Report your model's base parameter values for INCPAR in Table ME 9.4.

Table 9.4. *Base and Updated INCPAR Parameter Values*

	Base Parameter Values		Updated Parameter Values
	USA	ROW	ROW only
Tobacco			0.4
Agr/Mfg			*No change*
Services			*No change*

13. Define the macroprojections experiment
    > Select "Shocks" page tab
    > Using your calculated cumulative growth rates, define the shock for each of these parameters, for each region:
    Labor endowment: *qo*("LABOR", r,)
    Capital endowment: *qo*("CAPITAL", r,)
    Total factor productivity: *afeall*(ENDOW_COMM, PROD_COMM, r)
    Your shocks page should look like Figure ME 9.1.

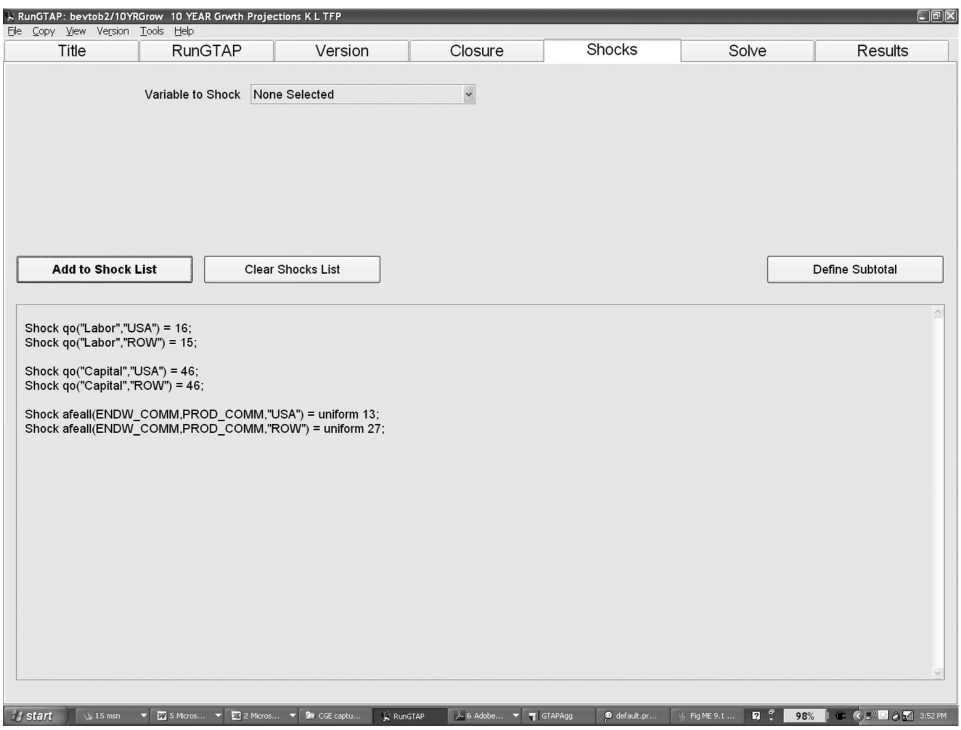


Figure ME 9.1. Shock page for the smoking preference experiment

Table 9.5. *Private Household Budget Shares Under Alternative Scenarios*

	Base		Income Growth		Income Growth with Row No-Smoking Preferences	
	USA	ROW	USA	ROW	USA	ROW
Tobacco	.013	.029				
Agr./Mfg.	.198	.387				
Services	.789	.584				
Total	1.000	1.00				

14. Save the experiment file
    > Select the "Solve" page tab
    > Check that the solution method is Gragg 2-4-6. If it is not, click on "Change," select Gragg from the box and then click on "OK"
    > Check that the parameter file is "Default". If it is not, click on "Change," select default.prm from the box and click OK.
    > Click on "Save experiment," name the shock MACRO, and describe it as "macroeconomic projections"
15. Solve the model
    > Click on "Solve"
    > OK
    > OK
16. Report model results in Tables ME 9.5, ME 9.6 and ME 9.7
    > To view budget share data:
    > Select "View" from the menu bar
    > Updated data
    > Updated GTAPView output
    > Double click on "Cost Structure of Consumption," or NPVA
    > Select "COL" in the menu box on the upper left hand corner of the page that says "None.". This calculates each cell as a ratio of the column total. In this case, the matrix displays budget shares of each commodity in total private household spending. Report your results to three decimal places.
17. Change consumer preferences for tobacco in ROW by changing the value of INCPAR. (For detailed instructions on changing an elasticity parameter and saving a new parameter file, see Model Exercise 3.)
    > Change INCPAR for tobacco in ROW to 0.4
    > Re-solve the model with the new parameter file and report results.
18. Carry out a systematic sensitivity analysis (SSA) of the degree of change in ROW attitudes about smoking as incomes grow (INCPAR). Follow the instructions in Model Exercise 3, and use the information below as your inputs to the SSA utility.
    > Parameter to vary: INCPAR in ROW
    > Percent variation: 100 percent (between close to zero and 0.8.)
    > Type of variation: Percent (this is the default choice)

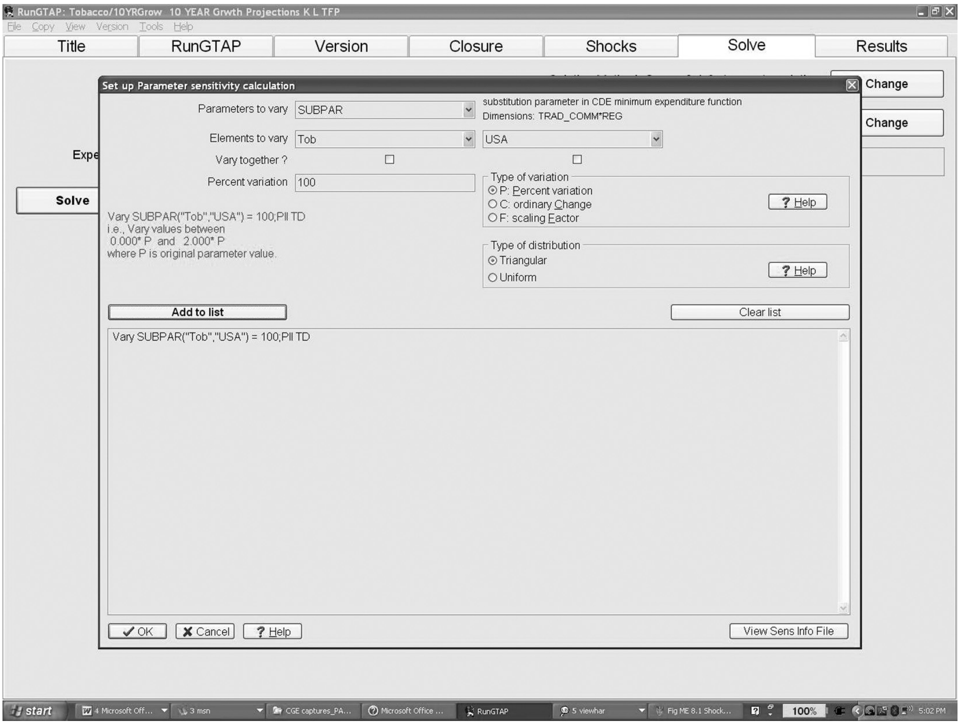


Figure ME 9.2. Systematic sensitivity analysis of INCPAR for tobacco in ROW

> Type of distribution: triangular (it is similar to a bell curve distribution and is the default choice)
> Name and save your two result files from the SSA by replacing the star in the file name with "Smoking" – without the quotes.
> Open and view the files with the sensitivity analysis results.

19. In Table ME 9.8, report the mean and standard deviation results for two variables: tobacco output, *qo*, in ROW and quantity of consumer demand, *qp*, for tobacco in ROW. Calculate the 95 percent confidence interval for both results, using Chebychev's theorem (see Text Box ME 3.1).

Table ME 9.6. *Change in Rest-of-World Household Budget Shares (% change from base)*

	Income Growth	Income Growth with ROW no-smoking Preference
Tobacco		
Agr./Mfg.		
Services		

Table ME 9.7. *Industry Output with and Without Changes in ROW Smoking Preferences (% change from base)*

	Income Growth		Income Growth with no-smoking Preferences	
	USA	ROW	USA	ROW
Tobacco				
Agr/Mfg				
Services				

Interpret Model Results

1. Provide an intuitive explanation of the INCPAR parameter and explain how the reduction in the value of INCPAR will affect ROW consumer demand as income grows.
2. Compare the base values for ROW's INCPARs for all three goods. Given these parameter values, how do you anticipate that growth in income will affect their relative budget shares in your base model scenario (with no preference change)? Are these expectations consistent with your model results?
3. Given the INCPAR parameters in the base model, how do you expect that income growth will affect industry structure? Are your results consistent with this expectation?
4. Develop your predictions for model results by drawing a graph that describes the market for tobacco in the ROW region. To keep it simple, ignore the effects of long-term economic growth on production.
   a. Draw a graph of the supply and demand for tobacco. Label the axes and curves, and label the initial market equilibrium, A.
   b. Draw the effect of an increase in income, assuming the base value of the INCPAR parameter, on the demand curve. Label the new market equilibrium, B.
   c. Draw the effect of an increase in income, assuming the new INCPAR parameter, on the demand curve. Label the new market equilibrium, C. How do the equilibrium quantities and price at C compare to those at equilibrium point B?
   d. Are the industry output results, *qo*, and price results, *ps*, from your two CGE model scenarios consistent with your simple theoretical model?

Table ME 9.8. *Systematic Sensitivity Analysis of Preference Changes on Tobacco Quantities in the Rest-of-World*

	Model Result	Mean	Standard Deviation	95 % Confidence Interval	
				Upper	Lower
Production (*qo*)					
Private consumption (*qp*)					

Source: GTAP CGE model and v.7.0 3x3 tobacco database.

5. Based on data from the SAMs for activity output in each country, how would you characterize the role of the tobacco sector in each economy? Based on these shares, how would you describe the likely size of economywide effects in each country of changes in tobacco preferences in ROW?
6. Write a short paragraph that describes your level of confidence in your model results for ROW's tobacco output, *qo*, and consumer demand for tobacco, *qp*. *Challenge:* present your results and your confidence interval in a graph, similar to that presented in Model Exercise 3.