



Model Exercise: Robert Solow and Total Factor Productivity Growth

You will learn how to change total factor productivity in an activity. You will learn how to identify and explain both the *direct* effects and the *indirect*, general equilibrium effects of productivity growth on an economy.

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1. INTRODUCTION

Robert Solow, a Nobel prize-winning economist, studied the determinants of economic growth. His most influential contribution was the idea that there are two separate determinants of growth. One is growth in the supply of factor inputs – labor and capital. When a country’s factor endowments grow, so will the quantities it is able to produce. The second determinant is technological progress, which increases the productivity of factor inputs. Growth in *total factor productivity* (TFP) allows the same quantity of all factor inputs to generate more output.

Solow’s ideas can be expressed as the equation:

$$Y = A(K,L)$$

where Y is national income, A is an exogenous technology parameter and K and L are the national endowments of capital and labor, respectively.

The Solow growth equation is incorporated into the production function in the UNI-CGE model as:

$$QA_a = \alpha_a * \sum_{f,a} (QF_{f,a}^{-\rho_a})^{-1/\rho_a} ;$$

where α_a is the total factor productivity parameter for production activity a ; variable $QF_{f,a}$ is the quantity of factor f used in activity a ; and parameter ρ_a is a transformation of the factor substitution elasticity, $ESUBVA$, for activity a , into an exponent term.

Notice that productivity growth in the UNI-CGE model is defined over the set of activities, a . This allows the modeler to define total factor productivity growth in some or all production activities.

In this model exercise, you will explore the effects of TFP growth in one sector of the U.S. economy, manufacturing, and identify both the *direct* effects on the MFG sector of the economy and selected *indirect, or general equilibrium*, effects on the rest of the

economy.

2. MODEL EXPERIMENT

In this model exercise, we examine the direct and indirect effects of a TFP shock in MFG. Your experiment increases the initial value of the MFG productivity parameter *alphaa* by 10 percent. This means that the same quantity of factor inputs (labor and capital) in MFG now produce 10 percent more output. You will examine the direct effects of the TFP gain on the manufacturing sector, and the indirect effects of the TFP gain on the rest of the economy. This exercise uses the US333 database in the UNI-CGE model with the default closure and elasticity values.

3. INSTRUCTIONS

1. Review and follow the instructions in the “How to” Guides in the Course.
 - a. How to Run the UNI-CGE Model
 - b. How to Define, Run and Verify an Experiment
 - c. How to Read Results in the Excel File
 - d. How to Read Results in the Listing File
 - e. How to Read Results in the GDX File
2. Change TFP in US manufactures
 - a. Search for the term “Experiment” in the UNI-CGE model
 - b. Unfold the experiment “Change Total Factor Productivity” by clicking on the arrow on the left of the “`$OnFold`” command. This will open sample experiments that change TFP (Figure 1). In Figure 1, the first command increases parameter *alphaa* (TFP) in all activities “A” by 5 percent. The next command specifies that TFP in SER alone increases 5 percent. Notice the commands to display *alphaa* parameters before and after their values are

redefined in the experiment. This can help you validate your experiment.

c. Edit the third command, or add your own, that increases `alphaa` only in the manufacturing activity, A-MFG, by 10 percent more than the initial level of productivity.

Figure 1. Experiment to change total factor productivity

```
*EXPERIMENT - Change Total Factor Productivity
$onFold
Display alphaa;
*alphaa(A) =alphaa(A) * 1.05;
*alphaa("A-SER") = alphaa("A-SER") * 1.05
*alphaa("A-MFG") = alphaa("A-MFG") * 1.02;
Display alphaa;
```

3. Complete the preparatory Checklist, then solve the model.

4. Verify the experiment Option 1 – search the .lst file.

Search from the bottom of the .lst file for “`alphaa`” (Figure 2). The top display of `alphaa` is the initial level of productivity. The bottom display should be 10% greater if you defined your experiment correctly.

Figure 2. Verify your experiment

The screenshot shows a GAMS .lst file with a search & replace dialog box overlaid. The dialog box is titled "Search & Replace" and has a search term of "alphaa". It shows 13 matches. The .lst file content includes:

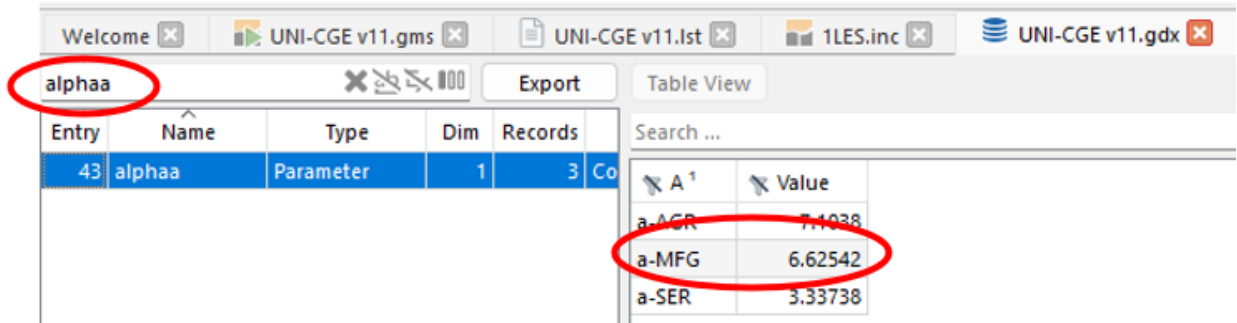
```
PRIV      100.0      100.0      100.0      100.0
TOTAL    100.0      100.0      100.0      100.0

---- 1699 PARAMETER alphaa Constant in CES p
a-AGR 7.104, a-MFG 6.023, a-SER 3.337

---- 1703 PARAMETER alphaa Constant in CES p
a-AGR 7.104, a-MFG 6.625, a-SER 3.337

GAMS 45.6.0 2eadeefd Jan 4, 2024 WEX
CREATE BASE and RESULTS TABLES
Equation Listing SOLVE UNI Using MCP From li
```

- Verify the experiment Option 2 – search the GDX file.
Open the GDX file and search for alphaa (Figure 3). The display should be level 6.62542 if you defined your experiment correctly.



4. EXPERIMENT RESULTS

- View Results Option 1: Excel Results File

Open the Excel UNI-RESULTS.XLSX file, located in your project directory.

Report the results of your experiment in Tables 1. Results in Table 1 are located in the Quantity, Prices and Factor worksheets in the Excel file.

Table 1. Direct effects of 10% TFP growth in US manufacturing (% change from base)	
Item	% change
MFG output quantity (QX)	
MFG producer sales price (PX)	
Labor employed in MFG (QF)	
Domestic demand quantity for MFG (QQ)	
Export quantity of MFG (QE)	
Import quantity of MFG (QM)	

- In the Excel UNI-RESULT.XLSX file, report the results of your experiment in Table 2. Results in Table 2 are located in the GDP, Macro and Quantity pages of the UNI-RESULTS.XLSX file.

Table 2. General equilibrium effects of 10% TFP growth in US manufacturing (% change from base)	
Item	% change
Real GDP (GDPMP)	
Private consumption (PRVCON)	
Investment demand (FIXINV)	
Gov't demand (GOVCON)	
Agriculture output quantity (QX)	
Agriculture export quantity (QE)	
Services output quantity (QX)	
Services export quantity (QE)	-2.4
Exchange rate (EXR)	-1.0

- View Results Option 2: GDY File

Search for these terms in the GDY file to locate results for Tables 1 and 2:

QF_PC – percent change in employment by factor and activity

RES_PCOM_PC – percent change in commodity prices

RES_PC_QCOM – percent change in commodity quantities

RES_SCAL_PC – percent change in scalar variables

RGDPTAB_PC – percent change in components of real GDP

5. DISCUSSION QUESTIONS

Model results for the US manufacturing activity reported in Table 1 are the *direct* effects on MFG of its TFP productivity gain. Model results in Table 2 are examples of the *indirect, general equilibrium* effects of the TFP growth in US manufacturing.

1. Explain the meaning of “direct” effects and “indirect” effects of a model experiment such as the TFP gain in U.S. manufacturing?
2. Why does MFG output increase but MFG demand for labor fall?
3. Why does an increase in input productivity cause the MFG producer price to fall?
4. Why does demand for MFG imports increase if MFG output also increases? Include the idea of production differentiation in your answer.
5. Why does domestic demand for MFG increase by less than the output of MFG?
6. What is the savings-investment closure in your model? What do you expect will happen to the marginal propensity to save? Could household savings still increase in your experiment? Does this explain the change in investment spending in your results?
7. Does the exchange rate appreciate or depreciate? Can you explain why?
8. Why does the decline in demand for labor by MFG lead to higher output in AGR and SER?
9. Why do exports of AGR and SER fall but their output increases?
10. Describe whether each discussion question addresses direct or indirect effects.